

Original Report

Enhanced surface dose via fine brass mesh for a complex skin cancer of the head and neck: Report of a technique

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Received 3 December 2013; revised 28 February 2014; accepted 5 March 2014

Abstract

Purpose: The use of fine brass mesh in conjunction with rotational intensity modulated radiation to enhance surface dose for a complex skin cancer of the head and neck has not previously been described.

Methods and materials: We present a case of locally advanced basal cell carcinoma with temporal bone erosion treated with rotational intensity modulated radiation via helical tomotherapy with brass mesh. In vivo surface dose was assessed at multiple locations to verify delivered surface dose. Phantom measurements identified the enhancement ratio with the addition of brass mesh, and evaluated impact on the underlying dose distribution.

Results: The brass mesh use was feasible and conformed well to the underlying surface. In vivo dosimetry identified excellent skin surface dose with a mean of 103% of the prescription dose at the surface (range, 97%-120%). Phantom measurements identified a surface dose enhancement ratio of 1.36, and 1.38, respectively, with placement of brass mesh. Clinically, the patient is without evidence of disease or major treatment sequelae at 12 months follow-up.

Conclusions: For complex cutaneous malignancies with irregular surfaces unsuitable for tissue equivalent bolus, brass mesh provides an alternate method of increasing surface dose if inadequate surface dosimetry is identified with phantom or in vivo measurements.

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Introduction

Radiation therapy for advanced skin cancers of the head and neck region poses unique technical challenges, with

need for comprehensive surface coverage coupled with complex underlying anatomy. The orthovoltage or en face electron fields suitable for skin cancers of less complex anatomic regions are frequently suboptimal in the head and neck region, potentially both overdosing underlying critical structures and underdosing tumor or tissues at risk due to perineural spread. Intensity modulated radiation therapy (IMRT) is an attractive approach due to the ability to sculpt dose around irregular target volumes, and is now

Conflicts of interest: None.

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standard for mucosal head and neck cancers. Helical tomotherapy (HT) is an inverse planned, rotational IMRT technique with excellent conformality that in select circumstances may reduce dose to critical structures beyond that achieved with static field IMRT planning.^{1,2} However, the use of HT and other rotational and nonrotational IMRT techniques can prove challenging for superficial skin cancers due to potential differences between calculated and delivered surface dose,^{3,4} with several studies suggesting overestimation of delivered surface dose with some planning systems. The addition of tissue equivalent bolus (TEB) increases surface dose; however, TEB affects underlying dose distributions and placement over irregular surfaces may result in significant air gaps that compromise dose enhancement. In 2008, the Radiation Oncology Department at our institution began using a fine brass mesh (Whiting and Davis, North Attleboro, MA) as an alternative bolus.

The use of a fine brass mesh as an alternative to TEB results in enhanced dose to the skin, resulting primarily from production of secondary charged particles. Previous work in our department has demonstrated that use of brass mesh does not substantially perturb the underlying dose distribution or affect delivered monitor units.⁵ We report use of HT with daily application of single-layer brass mesh to increase surface dose for a locally advanced basal cell carcinoma of the ear with erosion of the underlying temporal bone.

Methods and materials

A 67-year-old patient presented with a neglected, ulcerated lesion of the right postauricular region, with near-complete involution of the pinna with remnant helix and lobule and involvement of the postauricular scalp, immobile off the underlying skull. Biopsy revealed basal cell carcinoma. The patient declined surgical resection,

which would entail a lateral temporal bone resection, scalp excision, and split thickness skin graft, and presented for definitive radiation therapy. The clinical target volume, determined by diagnostic computed tomography, physical examination, and known patterns of spread, included the involved skin and soft tissues with a 1.5-cm margin radially with coverage of the underlying temporal bone. An additional 3-mm circumferential margin was added for daily setup error to create a planning target volume (PTV). Due to the irregular PTV configuration and proximity to underlying brain, a conformal planning technique was selected. The TomoTherapy HI-ART treatment planning system (Accuray, Sunnyvale, CA) was used to create a conformal plan delivering 66 Gy over 33 daily fractions to the PTV while limiting dose to the underlying brain to a point maximum <60 Gy, with less than 2 cc to 55 Gy. The HI-ART planning system estimated a skin dose across the outer 3 millimeters of the target surface ranging from 60.78 to 76.79 Gy, with 96.4% of the outer 3 mm of the PTV receiving the prescription dose. Axial, sagittal, and coronal screen shots from the treatment plan are shown in Fig 1A, B, and C, respectively.

Phantom dose verification and quality assurance

Thermoluminescence dosimeter (TLD) measurements were performed on the tomotherapy cheese phantom, a specially designed 30-cm diameter tissue-equivalent phantom for quality assurance measurements, using the patient's planned dose delivery with the isocenter shifted to position the dose distribution near the anterior surface of the phantom. Measurements were made at with 2 TLDs each at 2 different locations on the phantom surface with and without the addition of the brass mesh to assess the surface dose enhancement ratio. Three sets of readings were performed on separate days, using the same TLDs to minimize variability due to differences in TLD calibration.

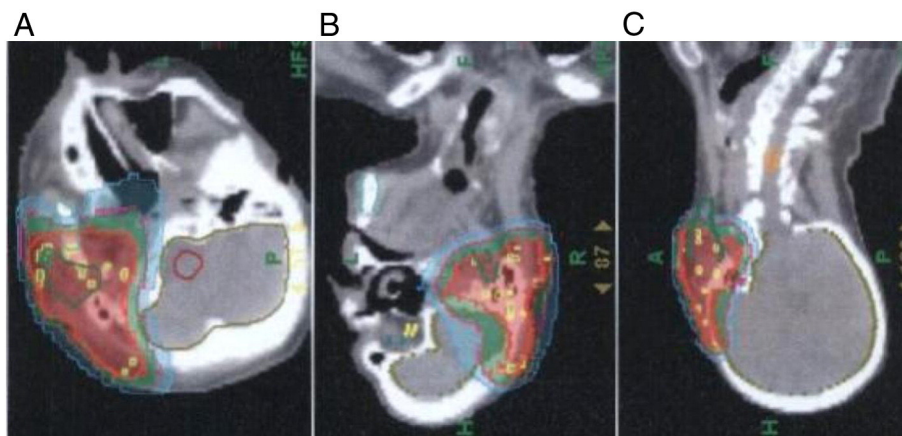


Figure 1 The TomoTherapy Hi-Art planning system was used to target the planning target volume to a prescription dose of 66 Gy in 2 Gy daily fractions. Axial (A), sagittal (B), and coronal (C) images are shown.

Patient dose verification and quality assurance

In vivo skin tumor dose measurements were obtained with TLDs on the first 2 days of treatment delivery, and suggested underdosing below 90% of the prescription dose (details not available). One layer of 2-mm fine brass mesh (Whiting and Davis) was then positioned over the skin surface, and TLDs were used on 2 consecutive days to obtain in vivo dose measurements of the skin surface at multiple locations both within the PTV and outside the target volume (Fig 2A) with the brass mesh in place (Fig 2B). Two calibrated TLDs were positioned at each location. Measurements with and without use of the brass mesh have previously been performed using a linear accelerator on a tissue-equivalent phantom in our department to assess impact of the mesh on the underlying dose distribution.⁵

Results

Phantom dose verification

Phantom measurements evaluating delivered dose with and without brass mesh application demonstrated a mean dose enhancement ratio of 1.36 and 1.38 at 2 separate locations on the phantom surface, respectively.

In vivo dose verification

Dose measurements obtained with TLD within the PTV on the skin surface over 2 days resulted in a mean dose of 206.8 cGy per fraction (range, 194–240 cGy), and all but 1 TLD reading was within 97%–105% of the prescription dose at the surface. One outlying TLD reading yielded a surface dose of 240 cGy/fraction; however, 2 additional TLD measurements at the same position both identified a dose of 200 cGy/fraction. The TLD readings obtained

under the mesh, ≥ 2 cm from the PTV, where the calculated skin dose was < 15 Gy, did not demonstrate clinically significant dose enhancement.

Patient follow-up

At a follow-up of 12 months, the patient remained in complete remission with no clinical evidence of skin cancer at the treated site. A small region of exposed bone without infection or soft tissue necrosis remained after treatment. Common Terminology Criteria for Adverse Events, version 4.0, grade 2 hearing loss developed in the right ear, with subjective loss of hearing not affecting activities of daily living. No other significant sequelae of treatment were identified.

Discussion

Definitive radiation therapy is frequently employed for locally advanced cutaneous and basal cell carcinomas when surgical resection would lead to severe disfigurement, or for those patients medically unable or unwilling to undergo resection. Definitive radiation therapy leads to local control in excess of 90% for early stage skin cancers, with more modest local control rates of 50%–60% at 5 years for T4 tumors or those with clinically apparent perineural invasion, with moderate risks of severe late toxicities.^{6,7}

Advanced skin cancers of the head and neck region may pose unique treatment planning challenges, dependent on the target volume configuration and adjacent critical structures. For relatively simple target volumes, conventional orthovoltage or electron fields remain preferable, due to ease of delivery, lower costs, and potential reduced risks of marginal failures. However, invasion of underlying bone, cartilage, or soft tissue, or perineural tracking creates complex target volume

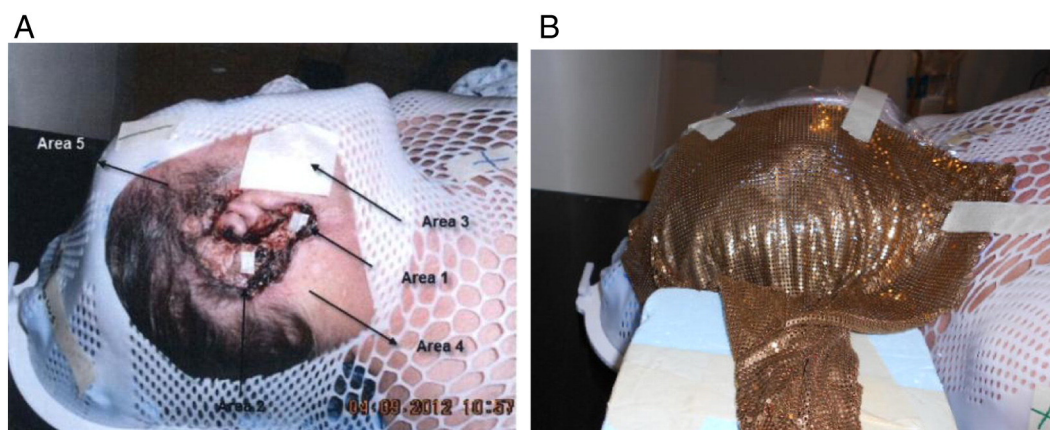


Figure 2 Thermoluminescence dosimeters were used to obtain in vivo verification of delivered surface dose on 2 days (A). A fine 2-mm brass mesh was applied over the surface of the treatment field daily (B).

geometry in close proximity to radiation-sensitive critical structures of the region, including underlying brain parenchyma, cochlea, optic apparatus, and oral mucosa among others. Intensity modulated techniques, including rotational approaches such as HT or volume modulated arc therapy are well established for treatment of mucosal head and neck cancers.

However, care is needed to ensure adequate surface dose when using advanced radiation planning techniques such as IMRT or rotational techniques targeting volumes that approach or involve the skin surface. Previously reported studies have demonstrated that, in particular, the HT HI-ART planning system frequently overestimates delivered surface dose by as much as 13%, necessitating *in vivo* dosimetry to ensure adequate coverage.^{3,4} Cheek and colleagues³ performed a dosimetric comparison between calculated and delivered dose with HT for superficial PTVs using a high-impact polystyrene phantom. The authors found that the planning system overpredicted delivered dose by as much as 9.5% within 1 cm of the surface. Ramsey et al⁴ assessed skin dose with an HT plan using an anthropomorphic phantom and found that surface dose was consistently overestimated by 3%-13%, and in test plans in which the PTV extended to the surface, the measured TLD dose was $86.6 \pm 5.1\%$ of the prescribed dose.

When inadequate surface coverage is identified, TEB is an option to increase surface dose. Its use with advanced radiation technologies to increase skin dose in the head and neck region has been previously reported, and in particular for total scalp treatment using HT.⁸⁻¹⁰ However, the relative rigidity of TEB creates challenges with irregular surfaces such as those encountered both with large, fungating primary tumors, and, dependent on tumor location, with the irregular surfaces of the face and neck.

Avoiding air gaps between skin and TEB surface often necessitates technically challenging customization of wax bolus, which is also subject to potential for air gaps and daily variations in positioning. Additionally, as the use of TEB affects underlying dose distributions, its use must be accounted for in both the simulation and treatment planning process. Hence, *in vivo* dosimetry at the time of the first fraction cannot be used to assess whether bolus is needed without the potential need for replanning.

Two-mm fine brass mesh, alternatively, is thin, pliable, and readily conforms to irregular surfaces. Use of a fine brass mesh was previously described for postmastectomy radiation therapy to the chest wall, validated by *in vivo* dosimetry and clinical outcomes.⁵ The underlying dose distribution is unaffected by the application of the mesh. Skin dose may be adjusted based upon results in *in vivo* or phantom dosimetry by application of 1 or more layers of mesh to achieve the desired surface dose. In the present case, use of a single layer of brass mesh enhanced surface dose by a ratio of approximately 1.3, allowing delivery of full tumoricidal dose to the entire target volume and resulting in a complete clinical remission. *In vivo* dosimetry confirmed delivery of the full prescription dose to the PTV. Given the variability in surface dose encountered with highly conformal radiation therapy approaches, *in vivo* assessment of dose both with and without the mesh should be performed to optimize treatment for each individual patient.

Other moldable TEB alternatives provide similar ability to minimize air gaps, including molded paraffin or bees wax, hydrophilic organic polymer powder mixes, or thermoplastic sheets or beads. Such materials also provide a practical and functional solution to ensuring adequate skin dose for superficial tumors requiring IMRT. The

Table 1 Commercially available bolus products, associated approximate costs, and clinical features

Product type	Brand names ^a	Cost ^b	Comparison features
Brass mesh	Whiting & Davis No. 70 brass small flat spider mesh, Gold (Whiting and Davis, Attleboro Falls, MA)	\$94.50 (18 × 18 inches)	<ul style="list-style-type: none"> ● Reusable ● No molding, heating, or mixing ● Minimizes air gaps
Gel sheets	Superflab (Fluke Biomedical, Cleveland, OH) ElastoGel (Southwest Technologies, North Kansas City, MO)	\$70.50 (Superflab 30 × 30 × 0.5 cm)	<ul style="list-style-type: none"> ● Reusable ● No molding, heating, or mixing ● May produce air gaps
Thermoplastic sheets or beads	Adapt-It Thermoplastic Pellets (Patterson Medical; Warrenville, IL) Aquaplast RT Custom Bolus (WFR/Aquaplast Corporation, Avondale, PA)	\$24.20 (1 lb Adapt-It Thermoplastic Pellets)	<ul style="list-style-type: none"> ● Nonreusable ● Requires heating/molding ● Minimizes air gaps
Paraffin or bees wax	Red Rope Wax (Heraeus Kulzer LLC, South Bend, IN) Bees Wax (Strahl & Pitsch Inc, West Babylon NY)	\$27/box of 55 ropes	<ul style="list-style-type: none"> ● Nonreusable, ● Requires heating/molding ● Minimizes air gaps
Powder mixes	Super Stuff (Balmar LLC, Lafayette, LA)	\$82 (50 oz Super Stuff)	<ul style="list-style-type: none"> ● Nonreusable, ● Requires mixing with water and molding ● Minimizes air gaps

^a Partial listing of commercially available products.

^b Cost approximate and provided in US dollars.

practical benefits to brass mesh over other products include the following: the simplicity and time savings inherent to a TEB alternative that does not require heating, molding, or mixing with water; the excellent conformality of fit; the ability to reuse the mesh on multiple patients; and the ability to apply bolus after in vivo dosimetry without replanning due to the lack of perturbation of the underlying dose distribution. Table 1 outlines several of the commercially available bolus products, associated approximate costs, and clinical features of each.

Conclusions

Brass mesh coupled with an advanced intensity modulated radiation planning technique provides a practical and logistically simple means of delivering full surface dose to cutaneous malignancies of complex anatomic regions. To our knowledge, this represents the first description of this technique in clinical practice and represents a novel use of the brass mesh in lieu of TEB.

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