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An Evaluation of Two Approaches to Skin Bolus Design for Patients Receiving Radiotherapy for Head and Neck Cancers

Andrew Luu, BMRSc, MRT(T)[ab*], Lilian Doerwald-Munoz, BSc, MRT(T), RT(T), CTIC[a] and Orest Ostapiak, PhD, FCCPM[ab]

[a] *Department of Radiation Therapy, Juravinski Cancer Centre, Hamilton, Ontario, Canada*
[b] *Department of Medical Physics and Applied Radiation Sciences, McMaster University, Hamilton, Ontario, Canada*

ABSTRACT

Purpose: This radiation treatment planning study compares two approaches to designing a bolus for patients with head and neck cancer. Our current approach, based on clinical examination, is compared with an alternative approach, based on the patient's computed tomographic image data set, to investigate potential improvements in delivering the prescribed dose to the superficial regions of the clinical target volume (CTV) while limiting the dose to normal skin.

Methods: Twelve consecutive head and neck radiotherapy plans requiring a bolus were selected. A clinically placed bolus was designed by a radiation oncologist through physical examination of the patient. A virtual bolus was designed using an algorithm that configured it to overlay only the superficial CTV delineated on the patient's CT data set. These two approaches were compared on the basis of dose-volume histograms of normal skin and the superficial CTV, as well as the total bolus area.

Results: Of 12 patients, the virtual bolus plan resulted in a decrease in the bolus area of at least 4 cm^2 for nine patients, an increase in the bolus area of at least 30 cm^2 for three patients, and an improvement in the minimum dose to the superficial CTV in six patients. Of these six patients, half had a reduction in the bolus area with a corresponding modest 2% improvement in the minimum dose to the superficial CTV, whereas the other half had an increase in the bolus area with a corresponding dramatic 10%–57% improvement in the minimum dose to the superficial CTV.

Conclusions: Basing bolus design on computed tomography image data rather than on clinical examination reduced the area of normal skin under the bolus in 9 patients (75%) and improved dose coverage of the superficial CTV in 3 patients (25%). All plans benefited from the virtual bolus approach because it has been shown to be more appropriate for balancing skin sparing with target coverage.

Keywords: Bolus; dosimetry; head and neck cancer; radiation therapy; radiotherapy

RESUMÈ

Objet : Cette étude de planification de radiothérapie compare deux approches de conception du bolus pour les patients atteints d'un cancer de la tête ou du cou. Notre approche actuelle fondée sur l'examen clinique est comparée à une autre approche basée sur l'ensemble d'images CT du patient afin d'étudier des améliorations potentielles de l'administration de la dose prescrite aux régions superficielles du CTV tout en limitant la dose à la peau normale.

Méthodologie et matériel : Douze plans consécutifs de radiothérapie de la tête et du cou exigeant un bolus ont été sélectionnés. Le bolus positionné cliniquement a été conçu par un radio-oncologue après un examen physique du patient. Le bolus virtuel a été conçu à l'aide d'un algorithme qui l'a configuré de manière à ne recouvrir que le CTV superficiel délimité sur l'ensemble de données CT du patient. Ces deux approches ont ensuite été comparées selon des histogrammes dose-volume de la peau normale et du CTV superficiel, ainsi que selon la surface totale du bolus.

Résultats : Sur douze patients, l'utilisation du bolus virtuel s'est traduite par une réduction de la surface du bolus d'au moins 4 cm^2 chez neuf patients; une augmentation de la surface d'au moins 30 cm^2 chez trois patients; et une amélioration de la dose minimum au CTV superficiel chez six patients. Parmi ces six patients, la moitié ont eu une réduction de la superficie du bolus avec une amélioration correspondante modeste de 2 % de la dose minimale au CTV superficiel, tandis que l'autre moitié a eu une augmentation de la superficie du bolus avec une amélioration dramatique de 10 à 57 % de la dose minimum au CTV superficiel.

Conclusion : L'utilisation d'un bolus virtuel au lieu d'un bolus positionné cliniquement permet de réduite la surface de peau normale sous le bolus chez neuf patients (75 %) et d'améliorer la couverture de dose du CTV superficie chez trois patients (25 %). Tous les plans bénéficient de l'approche de bolus virtuel qui s'avère plus appropriée pour équilibrer la protection de la peau et la couverture de la cible.

* Corresponding author: Andrew Luu, BMRSc, MRT(T).
E-mail address: luu.andrew2@gmail.com (A. Luu).

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Introduction

When head and neck cancer patients undergo intensity-modulated radiation therapy (IMRT), superficial gross disease is included in the target volume. These areas of superficial disease require an overlying layer of bolus material to provide dose buildup. The presence of the bolus avoids inadequate dose or unwanted modulation of beam intensity at the skin surface [1]. At the same time, normal, uninvolved skin should not be under the bolus to benefit from skin-sparing effects of megavoltage beams [2]. Therefore, careful design and placement of bolus material are important.

Our existing workflow requires the radiation oncologist to clinically assess the need for a bolus. This assessment is based on visual inspection and palpation with reference to diagnostic and pathology reports to determine areas of superficial involvement. The prescribed bolus is then outlined on the skin. The bolus is fabricated from successive layers of gauze infused with petroleum jelly to an overall thickness of 1 cm and wrapped in thin plastic cling film. It is then trimmed to the outline on the skin and held in place during Aquaplast mask formation so that it either bonds to the mask or registers to the mask for correct placement. This bolus placement method is very similar to that described by Lin et al [3]. Using this method, the patient is immobilized with the bolus in place under the mask for computed tomographic (CT) imaging. In cases in which the bolus extends posterior where the mask tents away from the skin, it is held in place with a Surgilast tubular elastic dressing retainer.

Although this method lends itself to a streamlined workflow and ensures that the bolus is correctly accounted for in treatment planning calculations, it does not benefit from the CT image data used to define the clinical target volume (CTV). Consequently, situations may arise in which superficial CTV regions are not covered by the bolus or regions of normal skin are unnecessarily covered by the bolus. The frequency of the occurrence of these two situations has not been previously evaluated. It is our experience that some patients require an additional bolus to be placed after planning; however, this was not the case among the cases sampled. Cases in which the bolus covers too large an area are not uncommon; however, in practice, it is rare to trim away bolus that is already embedded in the mask.

An alternative approach involving a virtual bolus may be used to mitigate these problems. A bolus designed during treatment planning may be specifically tailored to overlay only superficial regions of the CTV, thus sparing dose buildup to normal skin. This virtual bolus must then be fabricated and positioned before patient treatment and typically requires an extra patient appointment for simulation to ensure that the virtual bolus is accurately realized.

This study aimed to compare these two approaches in terms of providing adequate dose buildup to superficial CTV regions while sparing normal skin.

Materials and Methods

Ethics approval was obtained to study 12 patients with head and neck planned for radiation therapy with a bolus from December 2011 to April 2012, selected using consecutive sampling. Patients are identified using the letters "A" to "L." Each patient was treated as planned with a clinically placed bolus. An alternative virtual bolus plan was developed for each patient by replacing the original 1-cm-thick bolus with the same thickness of the virtual bolus. The original bolus was removed using a zero-density override region. A virtual bolus was added using a density over-ride corresponding to the CT number representative of the original bolus. The method of bolus replacement is similar to that conducted by Thomas and Hoole [4]. The algorithm shown in Table 1 was used to construct the virtual bolus as depicted schematically in Figure 1.

Using this algorithm, the virtual bolus region may taper toward its edge and overlap the CTV with a margin of at most 1 cm. The CTV was not adjacent to eyes for any of the subjects in this study; however, if the virtual bolus construction method was to be adopted as routine, exceptions would be needed to avoid the bolus over the eyes and lips. In this planning study, the real bolus was not fabricated to match the virtual bolus. To facilitate fabrication, the projection of the virtual bolus onto the mask may be printed for use as a template. Note that the petroleum jelly gauze composite is quite malleable so the tapered edges of the virtual bolus evident in Figure 1 could be reasonably well reproduced.

All plans were developed using the Pinnacle^3 treatment planning system version 9.2. Plans were optimized using the direct machine parameter IMRT module, and the final dose was calculated using the convolution/superposition dose engine. All calculations were performed on a 0.25-cm cubic voxel dose grid and accounted for tissue heterogeneity through a CT number to electron density conversion. For all patients, clinical plans were developed and delivered with no modification to the clinically placed bolus. According to our in-house protocol, the CTV was expanded by a 5-mm margin to create the planning target volume (PTV). For those plans in which the clinically placed bolus did not fully overlay the superficial CTV, a target structure (optPTV) was created for optimization. The optPTV was created from the PTV by excluding regions within 5 mm of the external contour. The external contour encompassed the body and clinically placed bolus. This plan was recalculated on the virtual bolus geometry without modification of the original IMRT fields.

Dose statistics were collected for the regions of the superficial CTV and normal skin to compare plans with the clinically placed bolus and the virtual bolus. For this comparison, there are two scenarios: first, the clinically placed bolus may not adequately cover the superficial CTV, leading to potential cold spots in the CTV; and, second, the clinically placed bolus may overlap too much of the normal skin where it is not