ELSEVIER

Brachytherapy 17 (2018) 489−499

BRACHYTHERAPY

Physics

Experimental assessment of the Advanced Collapsed-cone Engine for scalp brachytherapy treatments

Brie Cawston-Grant[1,*], Hali Morrison[1,2], Ron S. Sloboda[1,2], Geetha Menon[1,2]

[1]Faculty of Medicine and Dentistry, University of Alberta, Edmonton, Alberta, Canada
[2]Department of Medical Physics, Cross Cancer Institute, Edmonton, Alberta, Canada

ABSTRACT

PURPOSE: To experimentally assess the performance of the Advanced Collapsed-cone Engine (ACE) for ^{192}Ir high-dose-rate brachytherapy treatment planning of nonmelanoma skin cancers of the scalp.

METHODS AND MATERIALS: A layered slab phantom was designed to model the head (skin, skull, and brain) and surface treatment mold using tissue equivalent materials. Six variations of the phantom were created by varying skin thickness, skull thickness, and size of air gap between the mold and skin. Treatment planning was initially performed using the Task Group 43 (TG-43) formalism with CT images of each phantom variation. Doses were recalculated using standard and high accuracy modes of ACE. The plans were delivered to Gafchromic EBT3 film placed between different layers of the phantom.

RESULTS: Doses calculated by TG-43 and ACE and those measured by film agreed with each other at most locations within the phantoms. For a given phantom variation, average TG-43− and ACE-calculated doses were similar, with a maximum difference of (3 ± 12)% (k = 2). Compared to the film measurements, TG-43 and ACE overestimated the film-measured dose by (13 ± 12)% (k = 2) for one phantom variation below the skull layer.

CONCLUSIONS: TG-43− and ACE-calculated and film-measured doses were found to agree above the skull layer of the phantom, which is where the tumor would be located in a clinical case. ACE appears to underestimate the attenuation through bone relative to that measured by film; however, the dose to bone is below tolerance levels for this treatment. © 2017 American Brachytherapy Society. Published by Elsevier Inc. All rights reserved.

Keywords: ACE; Dosimetry calculations; Scalp; High-dose-rate (HDR)

Introduction

Recent developments in brachytherapy (BT) dose calculation have led to the commercial introduction of two model-based dose calculation algorithms (MBDCAs) that are available for ^{192}Ir high-dose-rate (HDR) treatment planning systems: the Advanced Collapsed-cone Engine (ACE) in Oncentra Brachy (OcB; Elekta, Stockholm, Sweden) (1, 2) and Acuros, a grid-based Boltzmann solver in BrachyVision (Varian, Palo Alto, CA) (3). These MBDCAs attempt to address dose calculation inaccuracies that can occur when the conventional water-based Task Group 43 (TG-43) dose calculation formalism is used (4−11). By considering tissue and applicator material composition and density, MBDCAs account for the effects of heterogeneities on dose. It is expected that dose calculation algorithms that can handle heterogeneities will especially benefit BT treatments that use shielded applicators or are near air or bone, such as the breast, skin, and head and neck treatments. For practical reasons, MBDCAs attempt to balance computational speed with dose calculation accuracy to achieve calculation times that are reasonable for clinical applications. The report from the American Association of Physicists in Medicine TG-186, which provides guidance for users of MBDCAs for BT, strongly recommends benchmarking the algorithms against Monte Carlo (MC) simulation and experimental measurements before clinical implementation (12).

ACE became clinically available with OcB v4.5 and allows for the consideration of heterogeneities through

---

Received 24 August 2017; received in revised form 17 October 2017; accepted 17 October 2017.

Financial disclosure: The authors report no proprietary or commercial interest in any product mentioned or concept discussed in this article.

* Corresponding author. Faculty of Medicine and Dentistry, University of Alberta, Edmonton, Canada.

E-mail address: cawstong@ualberta.ca (B. Cawston-Grant).

https://doi.org/10.1016/j.brachy.2017.10.010

the use of CT images, applicator models, and manual material assignment (1). Papagiannis *et al.* compared TG-43, ACE, and MC for a virtual ^{192}Ir HDR BT treatment of breast cancer and found that ACE was successful in accounting for the lung heterogeneity and finite patient geometry (13). Others have compared MC to ACE for HDR prostate treatment and found ACE to underestimate the dose near the bone by up to 15% compared to MC (1, 6).

At our clinic, ^{192}Ir HDR BT is an option for treating nonmelanoma skin cancer (NMSC) of the scalp. The advantages of this treatment compared to orthovoltage photons or megavoltage electrons include the ability to achieve a conformal dose despite the curvature of the head, the rapid dose falloff that reduces dose to the brain, and the ability to use hypofractionation to offset rapid tumor growth, or reduce the number of treatments for frail patients (14, 15). The objective of the work reported here was to evaluate the ability of ACE to calculate dose for a range of heterogeneities corresponding to clinically relevant situations. To accomplish this, we performed an experimental assessment of ACE for a variably configured, multilayered slab phantom using radiochromic film measurements. Differences between TG-43– and ACE-calculated doses (D_{ACE}) and film-measured doses were used to evaluate ACE and assess the potential clinical impact of heterogeneity-induced dose variations.

Methods and materials

Scalp phantom, film, and OcB

Custom-made surface molds used at our clinic for HDR BT treatments of NMSC are created by first making an impression of the patient's head with a thermoplastic shell. Next a thermoplastic bolus is added over the region identified as the clinical target volume (CTV) (includes the gross tumor area plus a margin), and catheters are adhered to this plastic bolus with 10-mm spacing. Then a layer of wax is overlaid on the catheters to provide backscatter. An experimental slab phantom was designed to model the constituents of the head (skin, skull, and brain) and mold using tissue-equivalent and water-equivalent materials (Fig. 1). The thicknesses of the layers were determined by examining the CT data sets of 3 scalp BT patients for skin thickness, skull thickness, air-gap size between the mold and head, and mold thickness. Layer thicknesses for each patient data set were determined by measuring and averaging the distances along the shortest paths between each catheter and the CTV (Table 1). Permission to use the images was obtained from the Health Research Ethics Board of Alberta Cancer Committee. Three variable parameters were selected for this study: air-gap size between the mold and head, skin thickness, and skull thickness. These parameters were varied from a standard phantom configuration (Phantom A). Table 2 summarizes the six variations of the slab phantom with varying layer thicknesses. Measurements were also performed in a phantom composed entirely of solid water (Phantom W). Phantom W had the same layer thicknesses as Phantom A, with solid water replacing the skull- and brain-equivalent layers and no air gap. For all phantoms, seven plastic catheters (6 F catheters with collar, Part # 110.800, Elekta, Stockholm, Sweden) were adhered to the top of the mold layer and were spaced 10-mm apart. A 10-mm thick wax backscatter layer was placed on top and in direct contact with the catheters. The slabs were obtained from Gammex (Sun Nuclear Corporation, Middleton, WI) and Scanplas Inc (Orpington, Kent, UK).

All radiochromic film measurements were made using Gafchromic EBT3 film (Ashland Specialty Ingredients, Wayne, NJ, lot #03181303 and #04201501). The film calibration curves were determined using a 6-MV photon beam from a Varian Clinac iX-S linear accelerator (Varian Medical Systems, Palo Alto, CA). Image analysis was performed in MATLAB v7.11 (MathWorks, Natick, MA). The methods used to perform the radiochromic film measurements are described in a later section titled "radiochromic film measurements."

TG-43 and ACE calculations were performed in OcB v4.5. ACE calculates scatter dose using collapsed-cone superposition convolution; full details of the algorithm are reported in a recent article by Ahnesjö *et al.* (2). ACE was commissioned using the test cases developed by the American Association of Physicists in Medicine Working Group on

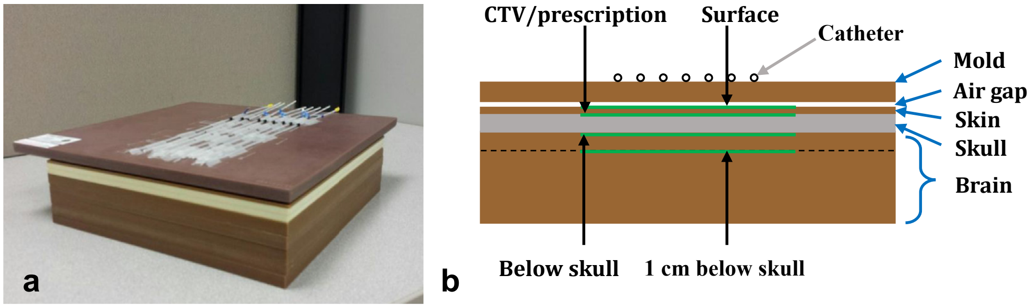

Fig. 1. Picture of slab phantom (a; variation B from Table 2) and interpretive schematic (b). The wax backscatter layer is not shown here. The black arrows identify the locations of film placement (exaggerated green lines) and the blue arrows identify the layers of the phantom. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)