Radiotherapy and Oncology xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Radiotherapy and Oncology

journal homepage: www.thegreenjournal.com

Original article

On the impact of improved dosimetric accuracy on head and neck high dose rate brachytherapy

Vasiliki Peppa [a], Eleftherios Pappas [a], Tibor Major [b], Zoltán Takácsi-Nagy [b], Evaggelos Pantelis [a], Panagiotis Papagiannis [a,*]

[a] *Medical Physics Laboratory, Medical School, National and Kapodistrian University of Athens, Greece; and* [b] *National Institute of Oncology, Budapest, Hungary*

ARTICLE INFO

Article history:
Received 4 November 2015
Received in revised form 18 January 2016
Accepted 18 January 2016
Available online xxxx

Keywords:
Brachytherapy
High dose rate
Head and neck
Dosimetry
Treatment planning

ABSTRACT

Purpose: To study the effect of finite patient dimensions and tissue heterogeneities in head and neck high dose rate brachytherapy.

Methods and materials: The current practice of TG-43 dosimetry was compared to patient specific dosimetry obtained using Monte Carlo simulation for a sample of 22 patient plans. The dose distributions were compared in terms of percentage dose differences as well as differences in dose volume histogram and radiobiological indices for the target and organs at risk (mandible, parotids, skin, and spinal cord).

Results: Noticeable percentage differences exist between TG-43 and patient specific dosimetry, mainly at low dose points. Expressed as fractions of the planning aim dose, percentage differences are within 2% with a general TG-43 overestimation except for the spine. These differences are consistent resulting in statistically significant differences of dose volume histogram and radiobiology indices. Absolute differences of these indices are however small to warrant clinical importance in terms of tumor control or complication probabilities.

Conclusions: The introduction of dosimetry methods characterized by improved accuracy is a valuable advancement. It does not appear however to influence dose prescription or call for amendment of clinical recommendations for the mobile tongue, base of tongue, and floor of mouth patient cohort of this study.

New dosimetry algorithms have recently become clinically available for ^{192}Ir high dose rate (HDR) brachytherapy [1,2]. These algorithms rely on models prepared from patient computed tomography (CT) imaging to account for tissue heterogeneities and the scatter conditions in the finite patient geometry, factors that TG-43 dosimetry disregards due to its inherent assumptions. This has stimulated retrospective studies on the effect of improved dosimetry for specific HDR brachytherapy sites [3–5]. Brachytherapy is indicated for squamous cell carcinoma of the oral cavity and oropharynx, either alone or as a boost after external beam therapy [6,7]. Besides a paucity of prospective studies, HDR challenges low dose rate interstitial brachytherapy which has a long history of excellent results, on account of the lower exposure to medical staff and the potential for dose optimization [6]. It is therefore interesting to study the effect of improved dosimetric accuracy in head and neck HDR brachytherapy, especially since one might intuitively expect this will be significant due to the limited dimensions and the involvement of air and bone tissues in the geometry that mark a significant departure from the radiological properties of water assumed in TG-43 dosimetry.

This study compares standard TG-43 dosimetry for a sample of 22 patients treated with HDR brachytherapy for tongue and floor of mouth carcinoma, to corresponding Monte Carlo (MC) simulation results, since the latter is considered the reference method for patient specific dosimetry.

Methods

Patient cohort

This comprised the plans of 22 consecutive head and neck patients treated with HDR brachytherapy at the National Institute of Oncology in Budapest, exported from PLATO v.14.6 in DICOM-RT format. Tumor sites included mobile tongue, base of tongue and floor of mouth. 9 patients had undergone prior surgery. 3D CT image based planning was performed. While dose optimization and dose prescription do not have an impact on results of this study, the following is reported for completeness. The planning aim was 15 × 3 Gy (definitive brachytherapy) or 7 × 3 Gy (boost brachytherapy) to be delivered twice daily with a minimum

* Corresponding author at: Medical Physics Laboratory, Medical School, Mikras Asias 75, 115 27 Athens, Greece.
E-mail address: ppapagi@med.uoa.gr (P. Papagiannis).

http://dx.doi.org/10.1016/j.radonc.2016.01.022
0167-8140/

interval of 6 h. Geometrical and graphical optimizations were applied followed by individual dose prescription. Dose was normalized to basal dose points and a reference relative isodose was selected to achieve at least 90% target volume coverage, keeping the dose homogeneity index above 0.55. When the geometry of the implant precluded meeting both objectives, priority was given to target coverage.

Dosimetry

The structures included in the treatment plans were limited to the PTV and, partly, the mandible. Seeking to augment the number of Organs at Risk (OARs) studied, the patient images were first processed to delineate the skin using a 4 mm contraction of the external patient contour. The plans were then imported into Oncentra Brachy v.4.5 and the parotid glands, spinal cord and mandible were delineated using Treatment Planning System (TPS) embedded tools. Dose was calculated over the whole imaging volume with 1 mm spatial resolution, using the TG-43 based algorithm of the TPS.

Patient specific dosimetry, taking into account anatomy and heterogeneities, was performed using version 6.1 of the MCNP general purpose MC code [8] and BrachyGuide [9]. The latter is a software tool for the automated configuration of MCNP input files based on the parsing of information from plans in DICOM-RT format. It is available as freeware via the web (http://www.rdl.gr/downloads) and its second version includes qualitative and quantitative dose distribution comparison besides DICOM-RT viewer and input file generation capabilities. The configuration of input files for MC simulation using BrachyGuide has been described in detail in the literature [9]. Absorbed dose was approximated by collision kerma, and medium kerma in medium was scored using the F6 tally in each voxel of the lattice geometry. The same number of photon histories was simulated for all patients (80×10^6). Statistical (type A) uncertainty, according to the codes' relative error estimates, was typically within 4% (less than 2.5% for the OARs and 0.5% for the PTV).

Comparison of TG-43 and patient specific dosimetry

TG-43 data in dicom RT Dose format and the MC output (patient specific dosimetry) for each patient were imported into the BrachyGuide software. After a review of 2D percentage dose difference maps superimposed on the corresponding planes of the CT image series, organ specific spatial information was discarded through the calculation of the relative cumulative Dose–Volume Histograms (DVHs) for the PTV and the OARs using 0.5% relative dose intervals. Comparison of results in the form of DVHs was further reduced to the comparison of single values of merit in common clinical use for each structure (PTV and OARs). These included the percentage of the structure receiving dose greater than given percentages of the planning aim dose (i.e. boost: 21 Gy, definitive: 45 Gy), V_x, the minimum percentage of the planning aim dose delivered at given volumes or percentages of a structure, D_x, the Dose Homogeneity Index (DHI) and the Conformity Index (COIN) for the PTV, and the mean and maximum structure dose (D_{mean}, D_{max}) as percentages of the planning aim dose, where appropriate [10–13].

In view of the different dose prescriptions in the patient sample, relative DVHs were also calculated in terms of the EQD2, the

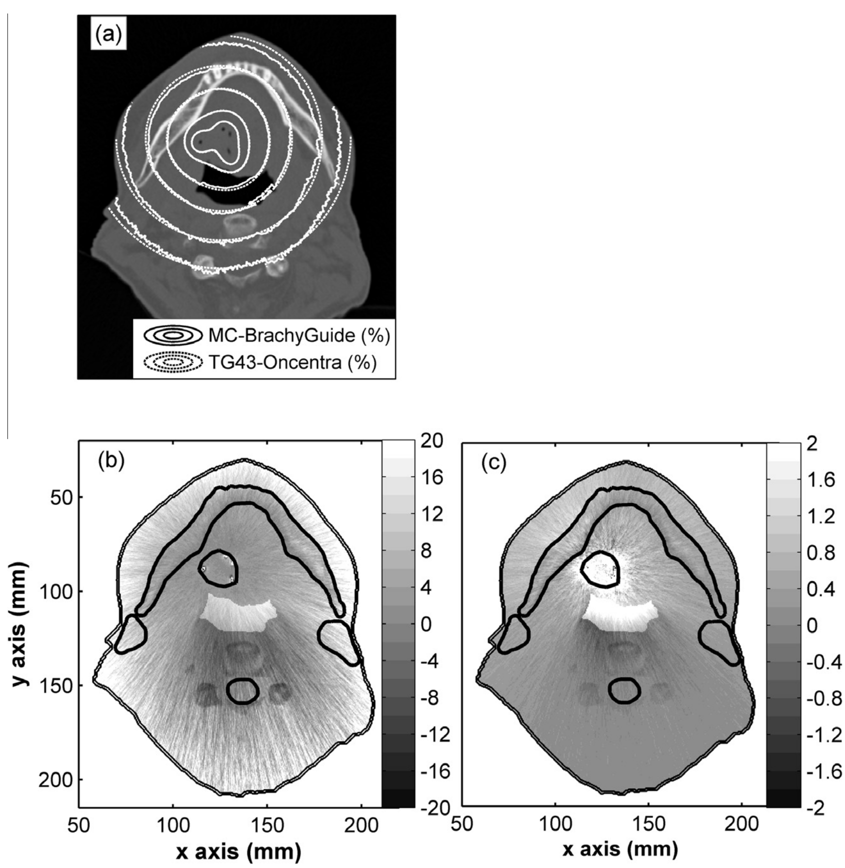

Fig. 1. TG-43 versus patient specific (MC) dosimetry on the central axial implant plane of an indicative patient. (a) isodose curves (3, 5, 10, 20, 50 and 100%) superimposed on the CT image (b) a colormap of % dose differences relative to MC,%$(D_{TG-43} - D_{MC})/D_{MC}$ (c) a colormap of % dose differences relative to the planning aim dose,%$(D_{TG-43} - D_{MC})/D_{PA}$.