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Can a commercial gel dosimetry system be used to verify stereotactic spinal radiotherapy treatment dose distributions?

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Abstract. This study investigated the use of the TruView xylenol-orange-based gel and VISTA optical CT scanner (both by Modus Medical Inc, London, Canada), for use in verifying the accuracy of planned dose distributions for hypo-fractionated (stereotactic) vertebral treatments. Gel measurements were carried out using three stereotactic vertebral treatments and compared with planned doses calculated using the Eclipse treatment planning system (Varian Medical Systems, Palo Alto, USA) as well as with film measurements made using Gafchromic EBT3 film (Ashland Inc, Covington, USA), to investigate the accuracy of the gel system. The gel was calibrated with reference to a moderate-dose gradient region in one of the gel samples. Generally, the gel measurements were able to approximate the close agreement between the doses calculated by the treatment planning system and the doses measured using film (which agreed with each other within 2%), despite lower resolution and bit depth. Poorer agreement was observed when the dose delivered to the gel exceeded the range of doses delivered in the calibration region. This commercial gel dosimetry system may be used to verify hypo-fractionated treatments of vertebral targets, although separate gel calibration measurements are recommended.

1. Introduction

Radiotherapy treatments of vertebral targets are challenging to plan and deliver, due to the geometry of the anatomy involved. It is especially important to verify the dose falloff between the targeted vertebra and adjacent spinal cord, and to establish that the spinal cord is adequately spared, for hypo-fractionated (stereotactic) treatments where elevated radiation doses are delivered over few fractions [1]. While valuable dose gradient information can be derived from two-dimensional film measurements in the coronal and sagittal planes [2, 3], the three-dimensional measurement capability of dosimetry gels gives them the potential to provide information about the consistency of the dose gradient, along the whole treatment volume, as well as a more comprehensive indication of the accuracy and deliverability of the planned dose.

This study investigated the use of a commercial gel dosimetry [4] system, for use in verifying the accuracy of planned dose distributions for vertebral treatments. Gel measurements were carried out and compared with planned doses and film measurements, to investigate the accuracy of the gel system and evaluate the suitability of a simple calibration method. In addition to providing an evaluation of a
specific gel dosimetry system, this study also provides a useful method for registering planned and measured 3D dose distributions, as well as an overall technique for evaluating commercial (or novel) gel dosimetry systems.

2. Method

Three different stereotactic ablative body radiotherapy (SABR) treatments were planned for vertebral targets, for delivery using a volumetric modulated arc therapy (VMAT) technique, using a Varian Truebeam linac with Millennium MLC (Varian Medical Systems, Palo Alto, USA). In all three cases, the prescribed dose to the planning target volume (PTV) was 24 Gy in 3 fractions and the maximum dose to the spinal cord was required to be below 17.5 Gy. Each of these treatment plans was copied onto a CT scan of a 20×20×10 cm³ water-equivalent plastic phantom, for comparison with a two-dimensional dose measurement made using EBT3 radiochromic film (Ashland Inc, Covington, USA), and also copied onto CT scans of three cylinders of TruView gel (Modus Medical Inc, London, Canada) for comparison with a three-dimensional gel dosimetry measurement.

The gel measurements were made using three standard 800 ml cylinders (9.6 cm diameter, 11 cm height) of ferrous-xylenol orange based TruView gel. All three samples were individually CT scanned, with radio-opaque markers used to indicate the scanning and irradiation setup position and aid in the registration of the 3D scanned image from the irradiated gel with the 3D dose distribution from the treatment planning system.

Gel handling and irradiations followed the recommendations provided by the manufacturer [5]. Gel results were read out using optical CT, using the VISTA optical CT scanner (Modus Medical Inc, London, Canada) [6]. During scanning the gel was immersed in a refractive index matching fluid made from mixing glycerol, water and food colouring, as recommended by the manufacturer [7].

Pre-irradiation optical CT scans of all three gel samples were acquired, with radio-opaque markers in situ. Additional radio-opaque markers were added to the gel containers after irradiation, so that marker positions would remain visible even after the post-irradiation optical CT scans of the gel were background-corrected [8] via the subtraction of the pre-irradiation scan data.

For irradiation using the three different vertebral SABR treatment plans, the gel samples were positioned with their longer dimension parallel to the linac couch’s longitudinal (craniocaudal) direction. The set up and delivery of each irradiation took less than four minutes. Optical CT scanning was completed 60 minutes after irradiation.

The film measurements were made with the film in the centre of the solid water, oriented in the transverse plane, and with one fraction from each of the test treatments delivered to each of three sheets of film. The handing, scanning and calibration of the EBT3 film was completed as previously described [9-11], with scans obtained before and after irradiation and results analysed using the red channel only.

3. Results

Figure 1 shows the quadratic calibration curve that was used to convert pixel values from all scans of the TruView gels into measured dose. This measurement result provides a strong indication that the dose-response of the TruView gel and VISTA readout system was non-linear. The dotted line shown in Figure 1 provides an indication of the degree to which the doses to out-of-field regions would be over-estimated if a linear dose-response was assumed (as is suggested by the manufacturer [5]) and combined with a renormalisation using the maximum dose (as is frequently applied in when gel dosimetry measurements are compared to clinical treatment plans [12]).
Figure 1. Calibration relationships (solid and dotted lines) derived from measurement data (diamonds) produced by irradiating a sample of TruView gel using one of the SABR test treatment plans and then assuming agreement between the planned and measured doses in a moderate-dose-gradient region (see Figure 2(a)). The solid line shows a quadratic fit to all data points. The dotted line shows a linear fit to the high-dose values only.

Figures 2(a)-(f) and 3(a)-(f) show profiles though the planned and measured doses from the three different spine SABR treatment plans. In all cases, the results of the film measurements agree closely with the planned treatment doses (mostly within 2%). The film measurement therefore confirms the accuracy of the treatment planning system’s dose calculation, so that the planned dose distribution can be used as the “ground truth” against which the gel measurement can be verified. Compared to the film results, the gel profiles show the effects of increased noise, decreased scanning resolution and decreased pixel bit depth.

The gel measurement shown in Figure 2(a) was used to derive the calibration data that was used to convert pixel values from all the gel measurements into dose (shown in Figure 1) and therefore shows the closest agreement with the planned dose. Of the other two gel measurements, the closest agreement with the treatment plan (and therefore with the film measurement) was achieved in the plan that was most dosimetrically similar to the plan used for the calibration (Figures 2(b) and 3(b)), while the poorest agreement was observed in the plan involving doses that substantially exceeded the maximum calibration dose (Figures 2(c) and 3(c)).

It is possible that the level of agreement between the gel measurements and the planned doses shown in Figures 2(a)-(f) and 3(a)-(f) may have been over-estimated, due to the calibration method chosen for use in this study. This calibration method lacks the independence of a separate calibration, and produces measurement results which are, by definition, unable to identify any inaccuracies in the dose measurement within the calibration region. Given the apparent non-linear dose response produced in the TruView gel by the hypo-fractionated treatments investigated in this study, it may be advisable to perform an independent calibration measurement (using small vials of gel irradiated to different doses or using a single gel sample irradiated using a known dose profile such as a percentage depth-dose or a wedged profile) whenever TruView gels are used to examine high-dose (stereotactic) treatments. (Note that the film was independently calibrated using reference films irradiated up to 3000 cGy.)
4. Conclusion

The results of this study suggest that for the relatively small target volumes involved in stereotactic spinal radiotherapy, TruView gel and VISTA optical CT scanner are able to approximate the doses measured using film, despite lower resolution and bit depth. Poorer agreement is observed when the dose delivered to the gel exceeds the range of doses used in the calibration. This commercial gel dosimetry system may be used to verify hypo-fractionated treatments of vertebral targets, although separate gel calibration measurements are recommended.
All doses reported in this study were calculated and measured within media with homogeneous densities. Routine quality assurance of vertebral SABR treatment plans should not use homogeneous media unless the treatment planning system has been thoroughly commissioned and shown to calculate dose accurately when highly modulated, high-dose treatments are planned for bony anatomy.

5. References
[1] Sahgal A et al 2008 Int. J. Radiat. Oncol. Biol. Phys. 71 652-65
[2] Kairn T et al 2016 Australas. Phys. Eng. Sci. Med. 39 325
[3] Kairn T et al 2016 Med. Dosim. 41 258-66
[4] Baldock C et al 2010 Phys. Med. Biol. 55 R1-63
[5] Modus Medical Inc, TruView Product Data Sheet, http://modusqa.com/images/resources/MMDI_TruView_PDS.pdf
[6] Olding T and Schreiner L J 2011 Phys. Med. Biol. 56 1259-79
[7] Modus Medical Inc, VISTA Product Data Sheet, http://modusqa.com/images/resources/Modus_Vista_PDS.pdf
[8] Trapp J V et al 2001 Phys. Med. Biol. 46 2939-51
[9] Aland T et al 2011 Australas. Phys. Eng. Sci. Med. 34 251-60
[10] Kairn T et al 2010 Phys. Med. Biol. 55 L37-42
[11] Kairn T et al 2011 Australas. Phys. Eng. Sci. Med. 34 333-43
[12] Kairn T et al 2012 Phys. Med. Biol. 57 3359-69