Physica Medica 45 (2018) 170–176

Contents lists available at ScienceDirect

Physica Medica

journal homepage: www.elsevier.com/locate/ejmp

Technical note

Quantifying the performance of two different types of commercial software programs for 3D patient dose reconstruction for prostate cancer patients: Machine log files vs. machine log files with EPID images

Noriyuki Kadoya[a,*], Yoshio Kon[a], Yoshiki Takayama[a], Takuya Matsumoto[a], Naoki Hayashi[b], Yoshiyuki Katsuta[a,c], Kengo Ito[a], Takahito Chiba[a], Suguru Dobashi[d], Ken Takeda[d], Keiichi Jingu[a]

[a] Department of Radiation Oncology, Tohoku University Graduate School of Medicine, Sendai, Japan
[b] Faculty of Radiological Technology, School of Health Sciences, Fujita Health University, Toyoake, Japan
[c] Department of Radiology, Takeda General Hospital, Aizuwakamatsu, Japan
[d] Department of Radiological Technology, School of Health Sciences, Faculty of Medicine, Tohoku University, Sendai, Japan

ARTICLE INFO

Keywords:
Radiotherapy
Quality assurance
EPID
Log file
Prostate cancer

ABSTRACT

We clarified the reconstructed 3D dose difference between two different commercial software programs (Mobius3D v2.0 and PerFRACTION v1.6.4).

Five prostate cancer patients treated with IMRT (74 Gy/37 Fr) were studied. Log files and cine EPID images were acquired for each fraction. 3D patient dose was reconstructed using log files (Mobius3D) or log files with EPID imaging (PerFRACTION). The treatment planning dose was re-calculated on homogeneous and heterogeneous phantoms, and log files and cine EPID images were acquired. Measured doses were compared with the reconstructed point doses in the phantom. Next, we compared dosimetric metrics (mean dose for PTV, rectum, and bladder) calculated by Mobius3D and PerFRACTION for all fractions from five patients.

Dose difference at isocenter between measurement and reconstructed dose for two software programs was within 3.0% in both homogeneous and heterogeneous phantoms. Moreover, the dose difference was larger using skip arc plan than that using full arc plan, especially for PerFRACTION (e.g., dose difference at isocenter for PerFRACTION: 0.34% for full arc plan vs. −4.50% for skip arc plan in patient 1).

For patients, differences in dosimetric parameters were within 1% for almost all fractions. PerFRACTION had wider range of dose difference between first fraction and the other fractions than Mobius3D (e.g., maximum difference: 0.50% for Mobius3D vs. 1.85% for PerFRACTION), possibly because EPID may detect some types of MLC positioning errors such as miscalibration errors or mechanical backlash which cannot be detected by log files, or that EPID data might include image acquisition failure and image noise.

1. Introduction

Highly conformal radiotherapy, such as intensity-modulated radiation therapy (IMRT) and volumetric arc therapy (VMAT) provide complex dose distributions with a sharp gradient, and patient-specific quality assurance (QA) is therefore necessary. Gamma index evaluation has become a standard technique used to compare measured distributions with calculated distributions by a commercial radiation treatment planning system [1]. A typical example of an acceptance criterion of 95% of points above a dose threshold must have a gamma index < 1 for dose difference and distance-to-agreement limits of 3% and 3 mm, respectively. A previous study demonstrated a lack of correlation between conventional IMRT QA methods and dose errors in anatomic regions of interest [2]. Zhen et al. also reported that the gamma passing rate has a weak correlation with critical patient dose volume histogram (DVH) errors. Based on these previous papers, gamma evaluation methods using phantom may not predict clinically relevant patient dose errors [3].

To tackle this issue, a patient DVH-based dose QA method has been developed [4–6]. Several papers discussed using the log file generated by the multileaf collimator (MLC) controller during IMRT and VMAT delivery as a tool for inverse dose verification for DVH-based patient-specific QA [7–9]. Several commercially available software systems aimed at providing DVH-based QA metrics using log files are already available [9–12]. For example, Mobius3D (Mobius Medical Systems, USA) and PerFRACTION (Sun Nuclear Cooperation, USA) are

* Corresponding author at: Department of Radiation Oncology, Tohoku University Graduate School of Medicine, 1-1 Seiryo-Machi, Aoba-ku, Sendai 980-8574, Japan.
E-mail address: kadoya.n@rad.med.tohoku.ac.jp (N. Kadoya).

https://doi.org/10.1016/j.ejmp.2017.12.018
Received 4 May 2017; Received in revised form 18 December 2017; Accepted 23 December 2017
Available online 08 January 2018
1120-1797/

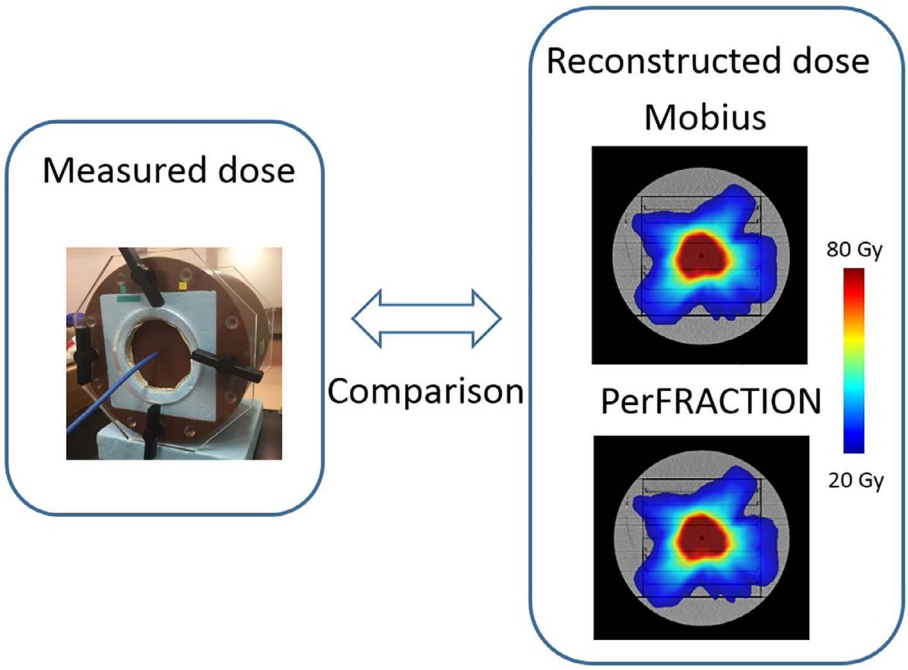

Fig. 1. Verification method of dose reconstruction methods: Measured dose vs. reconstructed dose by Mobius3D and PerFRACTION.

commercially available software packages that calculate the DVH-based QA metrics using log file. These two software programs can be used not only for pre-treatment patient-specific QA, but also for patient-specific QA in each fraction. These two software programs have different types of three-dimensional (3D) dose reconstruction methods: Mobius3D can reconstruct the 3D patient dose using only log file, whereas PerFRACTION can reconstruct patient dose using both log file and electronic portal imaging device (EPID) images. Several papers focused on the evaluation of the Mobius3D system have already been published, but there are no published data from PerFRACTION [9,13]. In addition, there are no data focused on direct comparison between Mobius3D and PerFRACTION regarding 3D patient dose.

Thus, we clarified the reconstructed 3D dose differences between two different types of commercial software programs.

2. Materials and methods

2.1. Mobius3D software program

Mobius3D employs a collapsed cone convolution algorithm independently developed and updated from its original conception [13,14]. This software calculates 3D patient dose using forward projection using machine log file.

2.2. PerFRACTION software program

This software calculates 3D patient dose using a forward projection technique which incorporates variations in delivered output and MLC positions from planned positions. The output of machine (MU), gantry angle, and treatment parameters are calculated by machine log file and the MLC positions are calculated by cine EPID images. The process for determination of MLC position using EPID followed 3 steps: 1) Computation of expected relative intensity profiles in the plane of the EPID based on the planned leaf positions (done via a ray tracing process through the planning CT image to the EPID). 2) Sorting and matching the set of cine images from delivery to the predicted images. 3) Derivation of actual leaf positions through analysis of the acquired images (done via edge detection). Since this process is proprietary technology, more detailed information cannot be provided by vendor. It should be noted that PerFRACTION uses EPID imaging only for determination of MLC position (i.e., leaf position and rotation). That is, EPID intensity cannot be used for forward projection techniques. The dose calculation algorithm was a superposition/convolution GPU-accelerated dose computation algorithm [10].

2.3. Patient characteristics and treatment planning

Five patients with prostate cancer treated with VMAT (74 Gy/37 Fr) were studied. All plans were created using the Eclipse version 11.0 (Varian Medical Systems, Palo Alto, CA, USA) with the analytical anisotropic algorithm for 15-MV beams from a Varian 23EX linear accelerator (Linac) with a Millennium 120 leaf MLC (Varian Medical Systems, Palo Alto, CA, USA). Planning computed tomography (CT) images were obtained on GE Light Speed RT16 (GE Medical Systems, Waukesha, WI, USA). Settings for acquisition of planning CT were 120 kV, 500 mA, and 0.8 ms. Scan parameters were set as follows: 9.37 mm/rot helical pitch, 10 mm beam collimation, 16 × 0.625 mm detector collimation, and 2.5 mm slice thickness. Log file and cine EPID images (8 frames/image) were acquired for each fraction. In terms of machine log file, the MLC controller of the Varian Linac creates a DynaLog file. The most relevant information contained in the log-file is the fractional MU, the segment number, and the calculated and reported position of each leaf. These data are acquired every 50 ms. In terms of the EPID image, EPID is a Portal Vision aS1000 imager (Varian Medical Systems, Palo Alto, CA, USA).

2.4. Verification of dose reconstruction methods

2.4.1. Homogeneous phantom

We re-calculated the treatment planning dose on a water-equivalent homogeneous cylindrical phantom (in-house) and then we acquired log file and cine EPID images with various acquisition rates (3, 4, 8, and 10 frames/image). All measurements were performed with a nominal dose rate of 600 MU/min. To validate the impact of acquisition rate for cine EPID images on 3D dose calculation of PerFRACTION, we used four different acquisition rates. We measured the dose at three points using a PTW 0.125 cm^3 Semiflex ion chamber (Type M31002, PTW, Freiburg, Germany) and compared the measured point dose with the reconstructed point dose in the phantom (Fig. 1). In addition, we created a skip arc plan to split the full-arc plan into 36 of sub-arcs (the interval