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Clinical practice and evaluation of electronic portal imaging device for VMAT quality assurance

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ABSTRACT

Volumetric-modulated arc therapy (VMAT) is a novel extension of the intensity-modulated radiation therapy (IMRT) technique, which has brought challenges to dose verification. To perform VMAT pretreatment quality assurance, an electronic portal imaging device (EPID) can be applied. This study's aim was to evaluate EPID performance for VMAT dose verification. First, dosimetric characteristics of EPID were investigated. Then 10 selected VMAT dose plans were measured by EPID with the rotational method. The overall variation of EPID dosimetric characteristics was within 1.4% for VMAT. The film system serving as a conventional tool for verification showed good agreement both with EPID measurements ([94.1 ± 1.5]% with 3 mm/3% criteria) and treatment planning system (TPS) calculations ([97.4 ± 2.8]% with 3 mm/3% criteria). In addition, EPID measurements for VMAT presented good agreement with TPS calculations ([99.1 ± 0.6]% with 3 mm/3% criteria). The EPID system performed the robustness of potential error findings in TPS calculations and the delivery system. This study demonstrated that an EPID system can be used as a reliable and efficient quality assurance tool for VMAT dose verification.

Introduction

Introductions of new techniques have improved radiotherapy, but at the expense of treatment complexity. Volumetric-modulated arc therapy (VMAT), a novel extension of intensity-modulated radiation therapy (IMRT), is one these new techniques. This rotational therapy delivers prescribed dose in relatively shorter duration and has better dose conformity, uniformity, and normal organ sparing.[1–5]

Many dosimetric devices for patient-specific quality assurance (QA), such as MatrixX (IBA Radiation Dynamics, Inc., Edgewood, NY), Arc Check (Sun Nuclear, Inc., Melbourne, FL), and Delta 4 (ScandiDos, Inc., Uppsala, Sweden) have been developed for rotational therapy.[5,6] Portal dosimetry (Varian Medical Systems, Palo Alto, CA) is one of those dosimetry verification devices. The current generation of electronic portal imaging device (EPID) is composed of amorphous silicon and semiconductor materials. It is not only an imaging tool for treatment setup verification but is also an implement for dosimetry measurements.[7–13] Moreover, EPID is a convenient dosimetry QA tool with a relatively high resolution of 0.392 mm.

GLAaS is an algorithm used to derive absolute dose maps from portal images acquired with EPID. The algorithm was developed originally for pretreatment verification. It is a method to compare dosimetric measurements directly against treatment planning system (TPS) calculations. Van Esch *et al.* investigated EPID dosimetric characteristics (aS500/IAS2, Varian Medical Systems) and used them for IMRT dosimetry.[9] Nicolini *et al.* also tested a new version of the EPID GLAaS algorithm for machine quality assurance and used it for VMAT fields.[14,15] Fogliata *et al.* analyzed the EPID measurements for VMAT quality assurance in different centers.[16] However, the previous publications did not use other independent dosimetric systems to verify GLAaS and TPS calculations.

The study was divided into 3 parts. The first was to evaluate dosimetric characteristics of the EPID system (aS1000/IAS3). The tests included dose-response linearity, dose-rate dependence, and field sizes dependence. Both 6- and 10-MV photon energies were studied. In the second part, 10 VMAT plans were acquired by the radiographic film system, EPID static method, and EPID rotational method. Finally, the film measurements and the EPID measurements were analyzed and compared with the TPS calculations.

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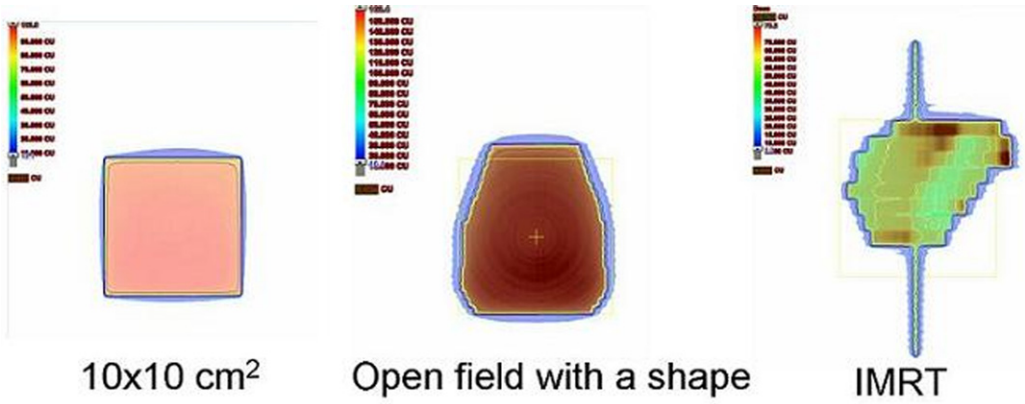

Fig. 1. Three patterns for dose reproducibility test. A 10 × 10-cm^2 field, an open treatment field, and an IMRT field. The images were achieved by EPID.

Methods and Materials

EPID acquisition description

Two C-linac iX linear accelerators (LINACs) (Varian Medical Systems, Inc.) with 120 multileaf collimators (MLCs) were used in this study. VMAT, which is named RapidArc, is available on the LINACs. During VMAT treatments, MLC position, gantry speed, and dose rate are modulated to deliver desirable doses.

The EPID system was composed of an image detection unit (IDU20), an image acquisition unit (IAS3), a robotic arm (Exact-arm), and a workstation. The detection area was 40 × 30 cm^2, which contained 1024 × 768 pixels. Each pixel consisted of a light photodiode with a thin film transistor. The pitch between each pixel was 0.392 mm. The incident x-ray hit the scintillating phosphor screen (Gd_2O_2S:Tb) and generated optical photons. The photons were absorbed by photodiodes, and signals were read out through an analog-to-digital converter. The signals were converted to absolute dose maps by the dosimetric calibration with GLAaS system on the workstation. The response of the detectors is a linear equation composed of primary and transmitted radiation. The total dose for each pixel is the sum of all segments. GLAaS is a method to calibrate EPID detector into dose rather than to predict the EPID response. The detailed rationale and application were described by Nicolini *et al.*[12,13]

Compared with other dosimetric systems, hardware such as developers and phantoms are not required for EPID systems. The system settings in this study were: there was no additional buildup on the top of the cassette and the position of EPID robotic arm was set to 0.0/0.0/0.0 (source-to-detector distance [SDD] = 100 cm). Dark field calibration, flood field calibration, and dosimetry calibration were required before the first use of the system. The dark field calibration was to correct background noise signal, and flood field calibration was to equalize EPID response through the whole area.[14] In dosimetry calibration, a diagonal beam profile measured at 5 cm depth of water was required for off-axis ratio correction. The calibrations were executed for different LINAC dose rates (range from 100–600 monitor units [MU]/min) and for different photon energies (6–10 MV). In practice, only one calibration mode can be selected for one measurement and each calibration mode was used for a specific dose rate and energy. After calibrations, 1 calibration unit (CU) of portal dose of EPID represented 1 cGy. In other words, raw images of EPID were converted to dose at 5 cm depth of water by GLAaS.

EPID characteristics

The dose reproducibility of EPID was evaluated by 3 different patterns, including a 10 × 10-cm^2 field, a 3D conformal field, and an IMRT field with sliding technique (Fig. 1). For each field, 3 measurements were compared with each other and they were acquired on 2 LINACs with the same mode EPID system.

The dose linearity of EPID was performed with MU ranging from 10–200. The average over an area of 20 × 20 pixels at field center was recorded for different MU. The differences were from the comparison of EPID to an ideal linearity.

The dose rate is varied in VMAT. Therefore, different LINAC dose rates (range 100–600 MU/min) were studied by delivering 100 MU. In addition, the response of using different EPID calibration modes was evaluated.

The EPID field size dependence was investigated by setting different field sizes ranging from 3 × 3 to 30 × 30 cm^2. The average over an area of 20 × 20 pixels at field center was normalized to that of a 10 × 10-cm^2 field. The value as a function of equivalent square field size was compared between EPID and 0.6 cm^3 farmer-type chamber (Exradin A12) measured at 5 cm depth in water.

One picket fence pattern proposed by Ling *et al.* was selected to test the EPID dosimetric system.[17] The pattern was originally one of the quality assurance tests for

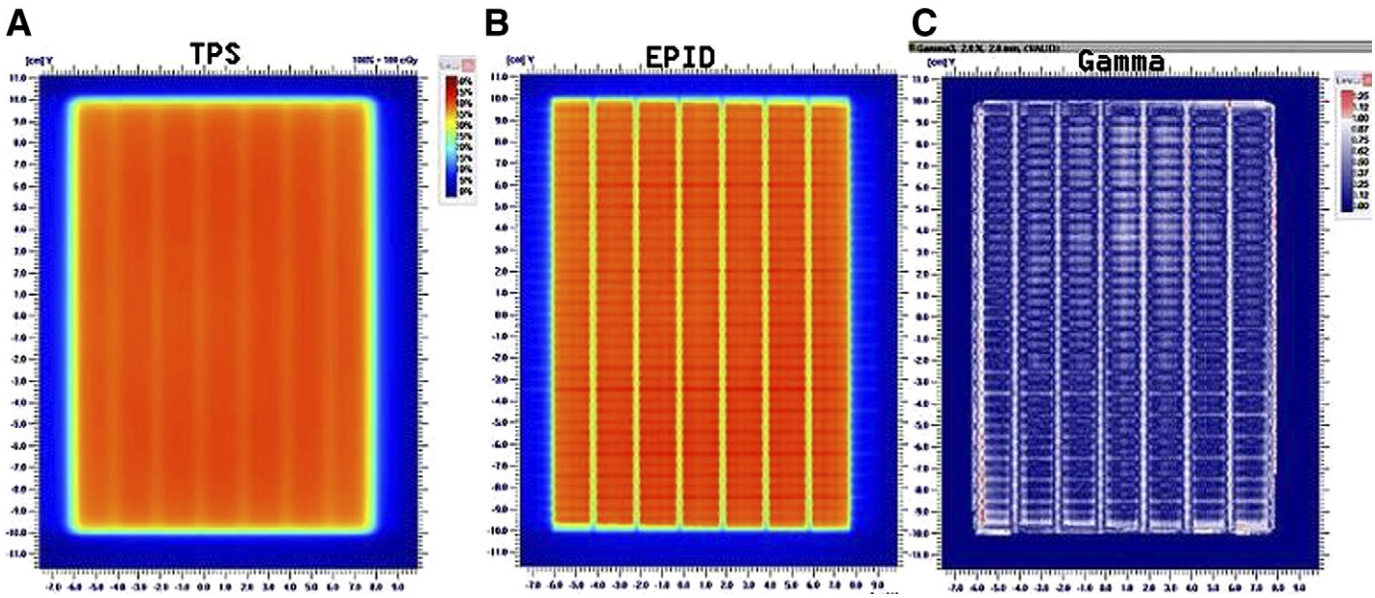

Fig. 2. The picket fence pattern for EPID dose verification: (A) TPS calculation; (B) EPID measurement; (C) GAI evaluation.