Dose Verification of Intensity Modulated Radiation Therapy with Beam Intensity Scanner System

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ABSTRACT

The intensity modulated radiation therapy (IMRT) with a multileaf collimator (MLC) requires the conversion of a radiation fluence map into a leaf sequence file that controls the movement of the MLC during radiation treatment of patients. Patient dose verification is clinically one of the most important parts in the treatment delivery of the radiation therapy. The three dimensional (3D) reconstruction of dose distribution delivered to the target helps to verify patient dose and to determine the physical characteristics of beams used in IMRT. A new method is presented for the pre-treatment dosimetric verification of two dimensional distributions of photon intensity by means of Beam Intensity Scanner System (BISS) as a radiation detector with a custom-made software for dose calculation of fluorescence signals from scintillator. The scintillator is used to produce fluorescence from the irradiation of 6MV photons on a Varian Clinac 21EX. The BISS reproduces 3D- relative dose distribution from the digitized fluoroscopic signals obtained by digital video camera-based scintillator(DVCS) device in the IMRT. For the intensity modulated beams (IMBs), the calculations of absorbed dose are performed in absolute beam fluence profiles which are used for calculation of the patient dose distribution. The 3D-dose profiles of the IMBs with the BISS were demonstrated by relative measurements of photon beams and shown good agreement with radiographic film. The mechanical and dosimetric properties of the collimating of dynamic and/or step MLC system alter the generated intensity. This is mostly due to leaf transmission, leaf penumbra and geometry of leaves. The variations of output according to the multileaf opening during the irradiation need to be accounted for as well. These phenomena result in a fluence distribution that can be substantially different from the initial and calculative intensity modulation and therefore, should be taken into account by the treatment planning for accurate dose calculations delivered to the target volume in IMRT.

Key words: IMRT, BISS, dose verification

1. INTRODUCTION

The development of Electronic Portal Imaging Device(EPID), although not water equivalent, has made it a tool for treatment verification and transmission dosimetry measurement.[1-13] Quality assurance(QA) systems for Treatment using the beam intensity scanner system(BISS) have been studied by us for static fields and dynamic fields. In order to use a BISS as an absolute dosimeter, a reliable calibration procedure is required to obtain the calibration curve that converts grayscale readings to portal dose. A typical calibration procedure involves irradiating the BISS with a different total dose, recording the readings, and independently determining the "reference dose," that is, an "estimate" of the portal dose at the detectors. The grayscale value versus the reference dose is plotted and the calibration curve is obtained either by interpolation/extrapolation or by function fitting in Fig. 1. The BISS-DVCS possesses suitable characteristics for relative 3D-dose measurements with laboratory-made program for verification of patient dose. The measurements of beam profiles for high-energy radiation, electron and photon beam, were carried out by the BISS-DVCS. The following routine or special radiotherapy applications were selected: dose profiles in high-energy photon used in IMRT and measurement of the relative 3D-dose distributions. Comparison of the results obtained with the BISS-DVCS and radiographic film are made where appropriate. The purpose of the leaf sequencing algorithm is to produce the desired fluence map once the beam is delivered, taking into consideration any hardware and dosimetric characteristics of the delivery system. Leaf sequence's configurations with the leaves during radiation delivery have been developed, and later modified to eliminate the hot spot regions overdosage effects on the interface of field sizes.

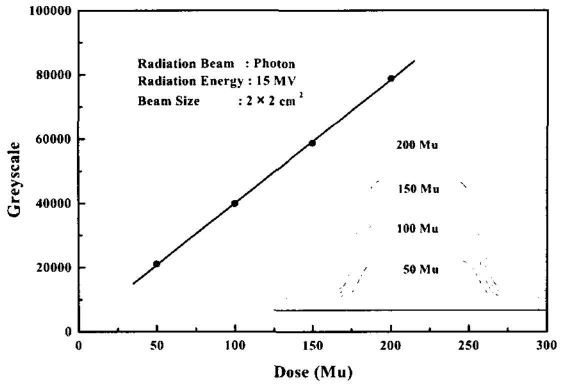


Fig. 1. The linearity of output reading with BISS-DVCS in arbitrary light intensity units and the values of calculation as function of relative absorbed dose in monitor unit. The insert figure shows that magnitudes of beam profile are in proportion to absorbed doses such as linearity.

In this work, we present a experimental study of the optimization of leaf spacing for the segmental multileaf collimator beam delivery and provide step dose distributions of optimized leaf space settings in delivered MU efficiency under various leaf movements.

2. MATERIALS AND METHODS

Varian 21EX Linac study is described leading to the optimization of a custom-made scintillation detector of a BISS-VCFD for megavoltage photons. This detector could allow low dose portal imaging and irregular shaped beams used in IMRT. The BISS-VCFD basically consists of a fluorescent screen, reflector, a CCD digital video camera, and personal computer. The fluorescent screen (scintillator) is a 1.8mm thick stainless steel plate coated with a layer (1.5mm thickness) of Gadolinium Oxysulphide for 6MV photon beam. The beams for radiation source were as follows. Photon beams of energy 6MV were generated with a Varian 21EX accelerator. The adjustable photon collimators were set from 1.0×1.0 to $10.0\times10.0\,cm^2$ for measurements.

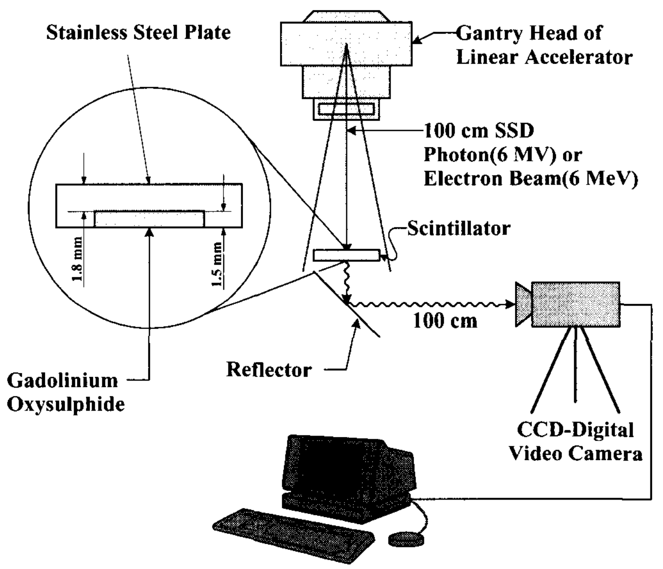
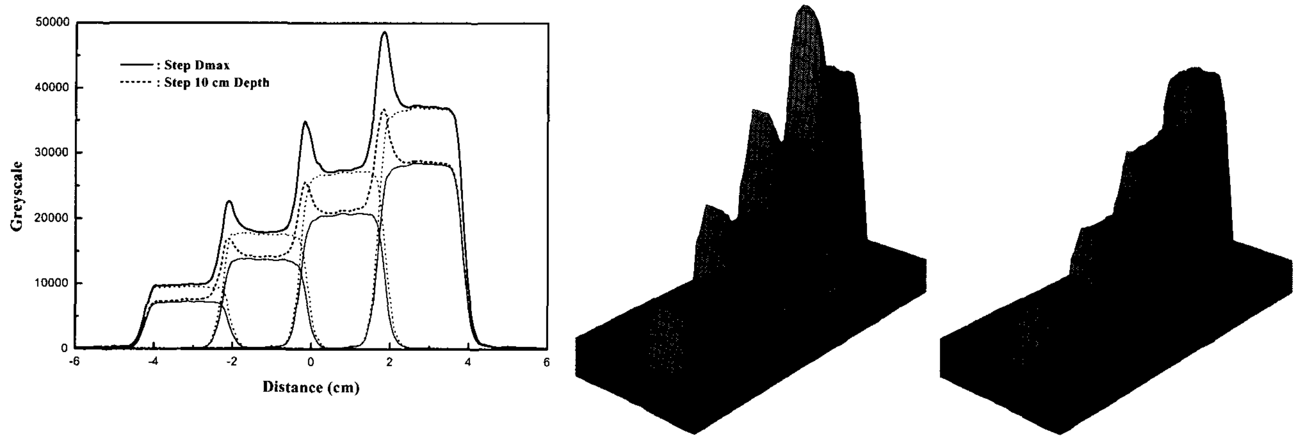


Fig. 2. The schematic of CCD digital video camera based fluoroscopic device is connected with computer to analyze data from scintillator.

The BISS-VCFD was irradiated perpendicular to the scintillator with the photon beam. The photons through the scintillator convert the fluorescent imaging into the beam intensity according to the positions on the beam sizes for photon. This incident fluorescent imaging that perpendicularly goes to one face of reflector is totally reflected at right angle to the other face which points to the CCD-Video camera. The acquired image has a fixed focus to digital CCD-Video Camera distance of 100 cm from the surface of reflector to reduce the scattering photons from gantry head shown in Fig. 2. The front end of fluorescent image aquisition device is BISS-VCFD which has 30 frames/second of speed. Once an image of radiation beam for cross section was generated at BISS-VCFD, the signal intensity was sent to video capture card in personal computer for data storage and analysis. The brightness of a pixel (600×600) in a certain position is proportional to the intensity of the irradiated beam passing through the dependence on position. Using this pixel brightness and radiation beam intensity relationship, the brightness of a pixel can be converted into a number along a selected line in the beam cross section and then consequently, this method could gives the 3D-dose distribution of beam profile reconstructed for the cross section.

3. RESULTS AND DISCUSSIONS

The 3D dose distribution measurements of photon beam from BISS-VCFD are almost identical for d_{max} and 10cm depth, but profile of d_{max} is slightly narrower than that of 10cm depth in shown Fig. 3 (a). The profiles of 10cm depth have only primary photons without scattered beams from gantry head because they almost are absorbed in the water phantom and the primary photon beams must be scattered. Resultantly, the peaks in the 10cm are broader shaped forms. The hot regions of interfaces in the 10cm still are dominant in shown Fig. 3 (b), we have to modulate the hot peaks to be flat shaped using adjusting of leaf spacing sequence on the interfaces of radiation field sizes in shown Fig. 3 (c). The profiles of square fields of 1.0×1.0 to 10.0×10.0cm^2 are the BISS for 6Mv photon beam at d_{max} in Fig. 4. All profiles show symmetry and are almost identical in shape, flat inside field. The small and large field represent steeper gradient in periphery. They are moor scattered photons out of penumbra region for large field than those of small field size. Computer controlled beam intensity modulated beam for three dimensional dose distribution is measured by BISS including MLC and dynamic wedges have been introduced in clinical practice in Fig. 5. By using dynamically controlled dose rate and collimator movement, dose can be optimally conformed to the target volume through the IMRT.



(a) (b) (c)

Fig. 3. Simple intensity modulated beams of three dimensional step shaped distributions. (a): beam profiles of step dose have hot regions on the interfaces for at d_{max} and 10cm depth, (b): three dimensional dose distribution of (a) case, (c) hot regions are eliminated by adjusting of leaf spacing sequence on the interface.

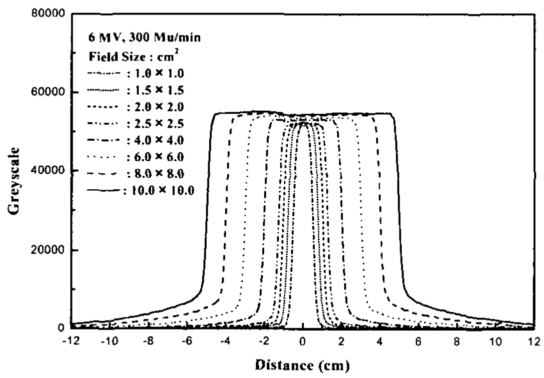


Fig. 4. The beam profiles as function of field size from 1.0×1.0 cm^2 to 10.0×10.0 cm^2.

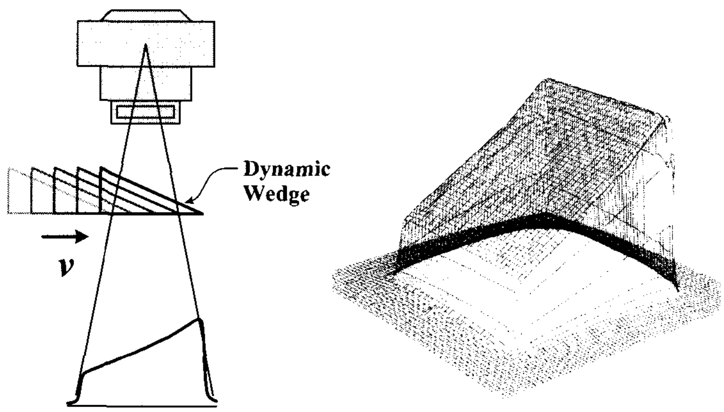


Fig. 5. The intensity modulated beam profile and 3-dimensional dose distribution using dynamic wedge.

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