Journal of BUON **9:** 303-306, 2004

ORIGINAL ARTICLE

Beam characteristics of kilovoltage radiotherapy unit

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Summary

Purpose: *To present the beam characteristics of the Siemens II orthovoltage x-ray therapy machine.*

Materials and methods: *x-ray beam qualities with the tube operating between 100 and 300 kV were determined. The field flatness, central axis depth dose, and relative output factors were measured for several applicator sizes for rectangular cones at 40 cm, and for circular cones at 30 cm focal skin distance (FSD).*

Results: *The central axis depth doses were selectively compared with values presented in the literature and found to agree to within ±3 % shallow depths for two energy ranges. The field edges had 85-95 % isodose line. Relative output factors of all the available cones were different.*

Conclusion: *The beam quality for all the stations should be determined and relative output factors should be measured for all the available cones.*

Key words: dosimetry parameters, kilovoltage x-ray beam, radiotherapy

Introduction

Kilovoltage (kV) x-ray therapy units are routinely used both for the cure or palliation of a wide variety of cancers. Examples of diseases typically treated in these units include basal and squamous cell carcinomas and metastatic bone cancer [1].

There has been a great deal of work done on the dosimetry of megavoltage photon beams in the past 30 years. The same can not be said for kV x-ray beams that are still used for radiotherapy. After the publication of the IAEA-1987 dosimetry protocol report [2], there has been renewed interest in the dosimetry of kV x-ray beams. KV x-ray beams have short ranges in water of electrons set in motion (0.1 mm for 300 kV), resulting thus in a negligible surface build up (no skin sparing). The absorbed dose to water for low energy beams is determined at the surface of a water phantom [3-5]. Air-filled ionization chambers are the prime instrument of absorbed dose determination for megavoltage radiation. For virtually any other dosimeters (e.g. thermoluminescence dosimeter, film, semiconductors) except ion chambers, one will achieve charged particle equilibrium in the sensitive medium of the detector as the electron ranges in this material [3-5].

This study describes the beam characteristics specific to the Siemens Stabilipan II orthovoltage unit including beam quality, depth dose, field flatness, and relative output factors. The purpose of this work was to present data that may be of some use for those who have already generated their own beam data, especially for outputs of small fields.

Received 18-03-2004; Accepted 29-05-2004

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Materials and methods

Siemens Stabilipan II orthovoltage machine is an x-ray generator with registered technique for superficial, semideep and deep therapy. Stabilipan II unit is used by two energy settings in our clinic. The combination of kV for this study is shown in Table 1. The unit has 3 close-ended rectangular cones of 6×8. 10×8 cm in diameter and 10×15 cm at 40 cm FSD, and 3 open-ended circle cones of 2, 3 and 4 cm in diameter at 30 cm FSD.

Beam quality measurements

Beam quality of the kV energy is defined as the first half value layer (HVL) and is characterized in terms of its attenuation in aluminum (Al) and copper (Cu). HVLs for 2 sets were determined in a narrow beam geometry by adding a filter [6]. The measurements were made in air using 0.6 cc NE 2581 Farmer type ion chamber.

Central axis depth doses

Depth dose measurements were made with a PTW 23344 parallel plate ion chamber with a sensitive volume of 0.2 cc, which is recommended to measure kV energy for selective depth and field sizes using custom-made collimators [7]. The chamber was placed on the surface of the Perspex slab phantom, which is designed for PTW 23344 ion chamber (Figure 1). Several slabs with different thicknesses were used. The electrometer readings were normalized to the surface reading.

Field flatness measurements

The field flatness for all cones was examined at the surface. Kodak X-Omat V verification films which are suitable to measure flatness for kV energy were used to determine the field flatness [6].

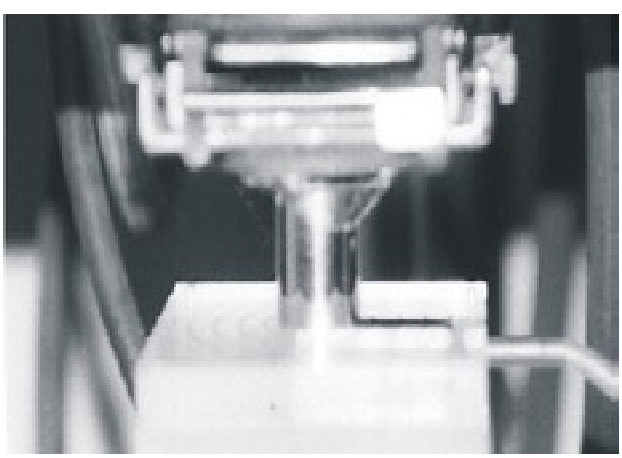

Figure 1. Experimental set-up for central axis depth dose measurements.

Relative output factor measurements for 200 kV 0.5 mm Cu filter (HVL=0.86 mm Cu)

Medium energy x-rays refer to x-ray HVL in the range of 0.5 to 4 mm Cu, or equivalently, above 8 mm Al, covering approximately those generated at tube voltages in the range of 160 to 300 kV. NE 2581 Farmer type ion chamber was placed with its centre at the reference depth of 2 cm in the Perspex phantom. Relative output factors for different field sizes for 3 rectangular close-ended cones were measured and normalized the dose of 10×8 cm cone at 40 cm FSD. The different square field sizes which were used to create square field using rectangular cones were prepared in our clinic. The difficulties associated with the dosimetry of narrow photon beams are well known in radiotherapy. The measurements of the circular cones were performed using a PTW 23344 parallel plate ion chamber with 0.2 cc sensitive volume, which is more suitable than the Farmer type ion chamber for smaller than 4×4 cm field sizes at 30 cm FSD. The measurements normalized the dose of 4 cm circle cone (the largest cone). Absorbed dose rate measurements for reference of close-end rectangular cone of 10×8 cm and 4 cm open-ended circle cone were made at a reference depth of 2 cm in the phantom using NE 2581 Farmer type ion chamber [4,5].

Relative output factor measurements for 100 kV 4 mm Al filter (HVL=3.5 mm Al)

Low energy x- rays refer to x-rays of HVL in the range of 1.0 to 8 mm Al, covering approximately those generated at tube voltages in the range of 50 to 160 kV.

Relative output measurements were performed with NE Farmer type ion chamber in air for different field sizes for 3 rectangular close-ended cones and normalized the dose of 10×8 cm cone at 40 cm FSD. The measurements of the circular cones were performed with a PTW 23344 parallel plate ion chamber in air and normalized the dose of 4 cm circle cone. Absorbed dose rate measurements were made using NE 2581 Farmer type ion chamber in air for the reference cone (4 cm circle opened cone) at 30 cm FSD. Absorbed dose rate at the phantom surface was found by multiplying the back scatter factor using the HPA protocol [4,5].

Results

The results of beam quality measurements are shown in Table 1. Figure 2 shows the results of central depth dose measurements at both energy ranges for

Table 1. Beam quality of two-set Siemens Stabilipan II as a function of filtration

Station	*I*	*II*
kV	100	200
Filter	4 mm Al	0.5 mm Cu
HVL_1	3.5 mm Al	0.87 mm Cu
HVL_2	7.2 mm Al	1.41 mm Cu

reference of the rectangular close-ended cone (10×8 cm) at 40 cm FSD. The results of the field flatness measurements show that all the cones used in the clinic indicate that, in general, beams are flat. The edges of the fields show a 85-95% isodose line. Figure 3 and 4 show the relative output factors, which normalized the 10×8 cm rectangular close-ended cone for both energy ranges at 40 cm FSD. Figure 5 shows the relative output factors, which normalized the 4 cm circle opened cone for both energy ranges at 30 cm FSD.

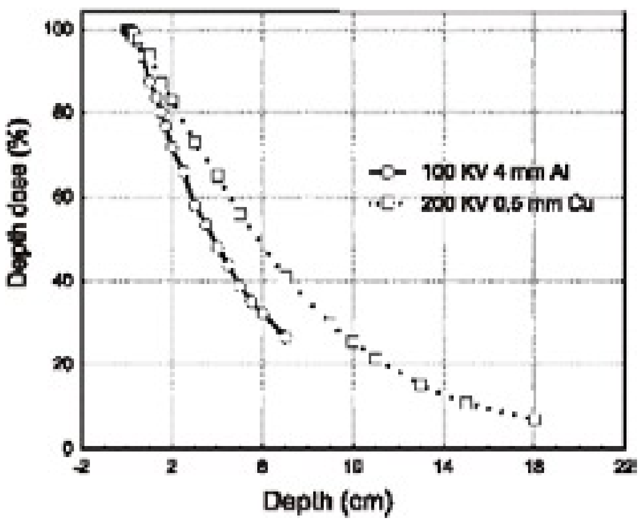

Figure 2. Results of central axis depth dose measurements for 10×8 cm close-ended cone at 40 cm FSD.

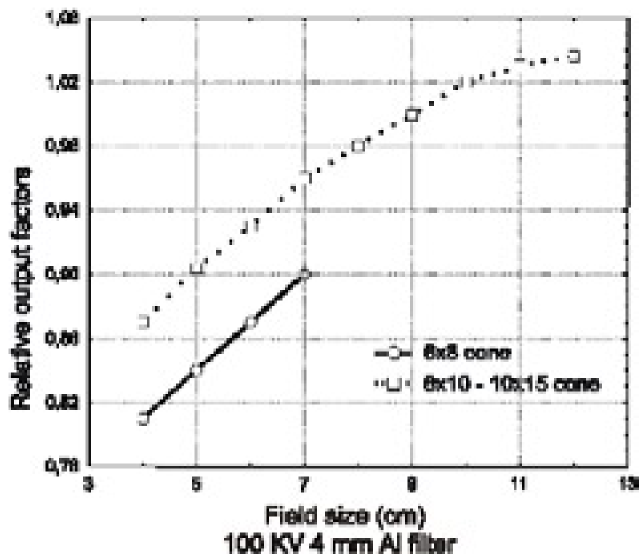

Figure 4. Relative output factors for close-ended rectangular cones at the range of 100 kV, 4 mm Al filter (FSD=40 cm).

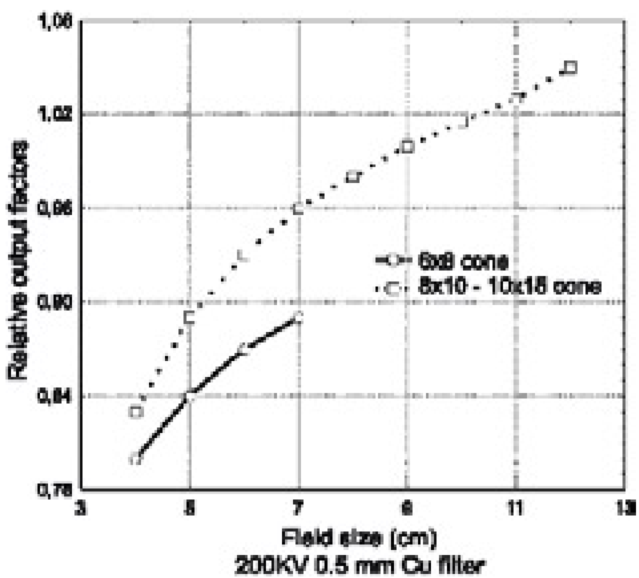

Figure 3. Relative output factors for close-ended rectangular cones at the range of 200 kV, 0.5 mm Cu filter (FSD=40 cm).

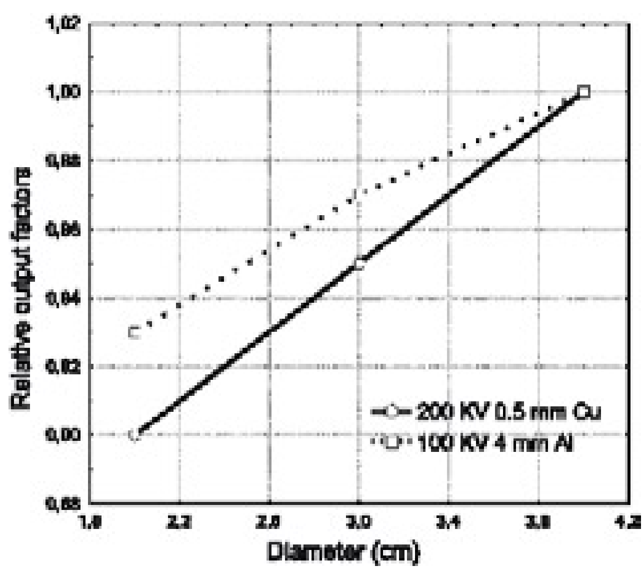

Figure 5. Relative output factors for open-ended circular cones at the range of 200 kV, 0.5 mm Cu filter and 100 kV, 4 mm Al filter (FSD=30 cm).

Discussion

Measurement of low energy (less than 300 kV) can present somewhat different problems than measurement of megavoltage energies. Proper choice of tissue equivalent phantom material and removal of very low energy photon electron contamination from the beam are important. Recommendations and systemic studies regarding relative dosimetry for kV x-ray beams are lacking in the literature.

The results of beam attenuation in Cu and Al are shown in Table 1 for two energy ranges. This information is useful in determining adequate thickness for custom-shaped fields, which are utilized for the patients. The central axis depth doses were selectively compared with values presented in [8] and found to agree to within ±3% shallow depths for two energy ranges and field sizes checked. At larger depths (>5 cm), the agreement was within ±5%. The results of the field flatness measurements indicate that the beam flatness decreases as the field size is reduced for two energy ranges. The field edge has 85-95% isodose line. This result is also adequate for coverage of a lesion [6,9]. Relative output factors were determined for all used cones and normalized reference field sizes. Figure 3 and 4 indicate that output factors of 10×8 cm and 10×15 cm cone are similar (±3%) until 8×8 cm square field. That's why output factors were shown in the same curve for those cones. Relative output factors of 6×8 cm cone were different than the others. Figure 5 shows relative output factors for circular open-ended cones for two energy ranges.

As a conclusion, beam quality for all the stations should be determined. This information is useful in determining adequate thickness for custom-shaped fields, and relative output factors should be measured for all the available cones to give precise dose to the patient.

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