Characteristics of 15 MV Photon Beam from a Varian Clinac 1800 Dual Energy Linear Accelerator

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A comprehensive set of dosimetric measurements has been made on the Varian Clinac 1800 15 MV photon beam.

Beam quality, percentage depth dose, dose in the build up region, output, symmetry and flatness, transmission through lead (Cerrobend), tray attenuation, isodose curves for the open and wedged fields were measured using 3 dimensional water phantom dosimetry system (including film densitometer system) and polystyrene phantoms. These dosimetric measurements sufficiently characterized the beam to permit clinical use.

The depth dose characteristics of photon beam is d_{max} of 3.0 cm and percentage depth dose of 76.8% at 10 cm, 100 cm source-surface distance, field size of 10×10 cm^2 for 15 MV X-ray beam. The Output factors ranged 0.927 for 4×4 cm^2 field to 1.087 for 35×35 cm^2 field. The build-up level of maximum dose was at 3.0 cm and surface dose was approximately 15.5% for a field size 10×10 cm^2. The stability of output is within $\pm1\%$ and flatness and symmetry are within $\pm3\%$. The half value thickness (HVL) of lead is 13 mm, which corresponds to an attenuation coefficient of 0.053 mm^{-1}. These figures compare favorably with the manufacturer's specifications.

Key Words: 15 MV Photon Beam, Linear Accelerator, Beam Quality, Depth Dose, Tissue-Phantom Ratio

INTRODUCTION

The Varian Clinac 1800 linear accelerator is a high energy radiation treatment machine that produces two photon beams and eight electron beams. The two photon beam include a low-energy mode selectable within 6 to 8 MV and a high-energy mode within 10-18 MV (Mega Voltage). The eight electron energies are selectable from 4 to 20 MeV (Mega electron Voltage). The Varian Clinac 1800 linear accelerator at our institution produces 6 and 15 MV nominal photon beams as well as electron beams of 6, 9, 12, 15 and 18 MeV. This series of Varian linear accelerator use standing wave guides mounted through a slewing ring mounting type gantry[1)].

A 5.5 MW (Mega Watt) Klystron provides the RF power to accelerate to the electrons down the wave guide[2,3)]. The bend magnet bends the electron beam through three 90 degree arcs (for a total of 270 degrees) to focus the beam onto the target[2)]. When the electrons leaving the accelerator guide encounter the first pair of bend magnet pole pieces, they are bent by amounts inversely proportional to their energies. The electrons with this energy spectrum then encounter a pair of slits. This slit allow only the electrons with energies within $\pm$ 3% of the nominal energy to pass on the second pair of pole pieces redirect the diverging electrons of different energies to an imaginary focus point in the third pair of pole pieces, by providing a long bending path for high energy electrons and a short path for low energy electrons.

All the electrons entering the third pair of pole pieces are brought to a focus on the target. The target is positional in and out of the electron beam path by a pneumatically-operated target drive mechanism. Air solenoids provide three different target position[3)]. The actual position of the target is dependent on which treatment has been selected. Any electron (E) mode is target fully retracted from beam. Low energy (X) mode is target inserted thin area in beam. High energy (X) mode is target inserted thick area in beam.

The X-ray beam (generated by high-energy electrons striking the target) passes through a series of tungsten collimators and is confined to the size of their apertures. First, the X-ray beam is confined to a projected 30 degree cone by the primary collimator, the X-ray beam next passes through the flattening filter (located on the crrousel), which attenuates the central axis of the beam more than the edge, making the beam uniform in flux intensity across its width of field sizes available on the machine. The criteria for flatness is ±3% over the central 80% of the field width for fields from 10 cm to 40 cm wide.

A set of orthogonal photon jaws collimator the beam allowing field sizes varying 0×0 cm to 40×40 cm at isocenter, 100 cm from the source. The machine has a 100 cm isocenter and can produce open beams and wedge beams of 15°, 30°, 45° and 60°.

The beam characteristics of various high-energy linear accelerators has brought out major qualitative differences in the beam characteristics among them. Such information has been useful to those planning to purchase or commission a high-energy linear accelerator and selecting the proper dose calculation thechniques for patients. A summary of dosimetric characteristics of 15 MV photon beam of the Varian Clinac 1800 is presented in this paper. This is based on a comprehensive set of measurements made at our institution on the Clinac 1800.

MATERIALS AND METHODS

Depth dose characteristics and beam profiles were determined using a computerized dosimetry system (MULTIDATA Corporation, St Louis, MO). The system consists of a cubic water tank of side 45 cm and PTW cylindrical ion chamber of sensitive volume 0.1 cm^3 biased to −300V and used in the ratio and single mode. The signals from the ion chambers were fed through an electrometer and a computer interface to a MULTIDATA RTD (Radiation Therapy Dosimetry) computer for analysis. The electrometer and computer interface were placed outside the treatment room to minimize electronic noise which may result from the radiation field in the vicinity of the accelerator. The computer controls all movements of the scanner and records the chambers integrated charge on a hard disk for subsequent processing. After the data have been collected, various computer programs can be run to calculate and plot depth dose, off axis profiles, or isodose curves. The data may be collected on a one or two-dimensional scan matrix. The points on the scan matrix are on a fan grid for the profile measurements, which are used for generation of isodose curves. For all measurements the phantom surface was kept at 100 cm source to surface distiance (SSD) and the field sizes were defined at that surface.

Measurements made in the build up region with the parallel plate chamber:# 30-404 Memorial Hospital parallel-plate ionization chamber. Ionometric measurements relating to the stability the accelerator output, wedge factor and tray factors were performed using a cylindrical ion chamber and a Victron 500 electrometer with the ion chmber in a polystyrene phantom. Measurements made in the variation dose over the whole plane with the film densitometer. Relative output factor were measured with the ion chamber in a water phantom in order to cover the largest possible field size.

RESULT

1. Central Axis Depth Dose

The central axis percent depth dose in water was measured for square fields from 4×4 cm to 35×35 cm at 100 cm source skin distance (SSD). The data for 15 MV photon beam is tabulated in Table 1. The data were normalized to measurements of ionization at depth 3.0 cm for 15 MV X-ray beam. These are the depths of maximum dose for a 10×10 cm field. All measurements were reproducible within ± 0.2%. The depth dose for a 10×10 cm field at 10 cm depth and 100 cm SSD is 76.8%. This agrees very well with the 77%±2% value quoted by the manufacturer[3].

The depth of dose maximum is 3.1 cm for 4×4 cm field size and decreases 2.1 cm when the field size is increased to 35×35 cm as Table 2. As expected, the depth of maximum dose shifts towards the surface as the field size increases[5,8,13].

Fig. 1 depicts depth dose curves for 4×4 cm, 6×6 cm, 10×10 cm, 15×15 cm, 20×20 cm and 25×25 cm field size.

Measurements made in the build up region with the 30-404 parallel plate chamber. The chamber was positioned on the central axis and all work was done at 100 cm SSD. Dose build up curves for 4, 10, 15, 20 and 30 cm square fields are shown in Fig. 2. As the field increases, the surface dose increases for the 15 MV photon beams. The values for the 15 MV X-ray beam range from 9.8% for the 4 cm square field to 43.3% for the 30 cm square field.

The percentage depth dose increases with an increase in the source to surface distance (Fig. 3). Considered the effect on the percentage depth dose at 10 cm depth due to an increase SSD from 100 to 120 cm. According to percentage depth dose at depth, the equation is

% depth dose at depth d

$$PDD = B\frac{f^2 e^{-\mu d}}{(f+d)^2} \times 100$$

which, for constant d, increase in f (SSD). The

Table 1. Percentage Depth Dose Data for 15MV X-ray SSD = 100cm, Normalized at 3.0cm Depth

Depth (cm)	Field (cm²)									
	4x4	6x6	8x8	10x10	12x12	15x15	20x20	25x25	30x30	35x35
0.0	25.9	27.9	30.6	33.3	35.9	39.2	45.4	49.9	53.2	56.4
1.0	76.5	77.7	79.3	81.4	83.4	85.4	88.9	91.4	92.4	93.3
2.0	96.2	96.3	97.1	97.3	98.0	98.9	99.8	100.6	100.9	101.0
2.5	99.0	99.1	99.3	99.4	99.9	100.2	100.5	100.8	100.8	100.9
3.0	100	100	100	100	100	100	100	100	100	100
4.0	98.2	98.3	98.2	97.6	97.7	97.5	97.1	97.1	97.0	96.9
5.0	94.9	94.9	94.8	94.2	94.3	94.1	93.6	93.5	93.5	93.4
6.0	90.6	91.0	90.9	90.7	90.6	90.5	90.4	90.3	90.3	90.3
7.0	86.6	87.3	87.3	87.0	87.1	87.0	87.0	87.0	87.0	87.0
8.0	82.6	83.5	83.5	83.6	83.7	83.7	83.8	83.9	83.9	84.0
9.0	79.0	80.0	30.2	80.2	80.5	80.6	80.6	80.7	80.9	81.0
10.0	75.1	76.1	76.6	76.8	77.1	77.2	77.6	77.7	77.8	78.0
11.0	71.8	72.8	73.3	73.5	74.1	74.1	74.5	74.6	74.9	75.1
12.0	68.6	69.6	70.2	70.4	70.8	71.2	71.6	71.9	72.1	72.4
13.0	65.4	66.4	67.1	67.4	67.8	68.2	68.7	69.1	69.4	69.6
14.0	62.3	63.4	64.1	64.6	65.1	65.5	66.2	66.5	66.9	67.2
15.0	59.3	60.5	61.3	61.9	62.3	62.9	63.4	64.0	64.2	64.6
16.0	56.6	57.8	58.6	59.1	59.6	60.4	61.0	61.6	62.0	62.1
17.0	54.0	55.2	56.0	56.6	57.2	57.8	58.6	59.2	59.6	60.0
18.0	51.6	52.8	53.7	54.2	54.9	55.6	56.3	56.9	57.2	57.6
19.0	49.2	50.4	51.4	52.0	52.5	53.3	54.0	54.8	55.1	55.5
20.0	46.9	48.2	49.1	49.6	50.3	51.1	51.8	52.6	53.0	53.4
21.0	44.9	46.1	47.0	47.5	48.2	48.9	49.8	50.5	51.0	51.3
22.0	42.9	43.9	44.9	45.6	46.3	47.1	47.7	48.6	48.9	49.4
23.0	40.9	42.1	43.0	43.7	44.2	45.1	45.9	46.7	47.1	47.5
24.0	39.1	40.2	41.1	41.7	42.4	43.3	44.1	44.8	45.3	45.6
25.0	37.3	38.5	39.3	39.9	40.6	41.5	42.3	43.1	43.5	43.9
26.0	35.7	36.8	37.7	38.3	38.9	39.8	40.6	41.3	41.8	42.2
27.0	34.1	35.2	36.1	36.6	37.2	38.1	39.1	39.8	40.2	40.6
28.0	32.6	33.6	34.6	35.1	35.8	36.6	37.6	38.1	38.7	39.0
29.0	31.2	32.2	33.0	33.6	34.3	35.1	36.1	36.7	37.2	37.6
30.0	30.0	31.0	31.9	32.2	33.1	33.9	34.8	35.3	36.0	36.2

Table 2. Dmax Depth of 15MV X-rays

Field size (cm²)	4x4	6x6	8x8	10x10	15x15	20x20	25x25	30x30	35x35
Dmax Depth (cm)	3.1	3.0	3.0	3.0	2.7	2.6	2.4	2.3	2.2

factor $e^{-\mu d}$ is a constant in cases and the factor $f^2/(f+d)^2$ increases from 0.826 to 0.852. This implies an increase of 2.2% in the percentage depth dose. However, since the primary radiation is only a part of the total exposure and scatter factor(B) becomes increasingly important with depth.

2. Tissue Maximum Ratio

For high-energy isocentric treatment machines, it is common to use the concept of Tissue-

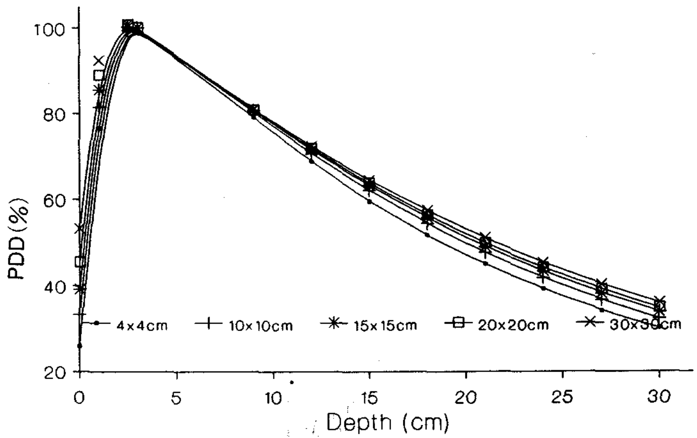

Fig. 1. The Percentage depth dose of 15 MV X-ray for various field size at 100 cm SSD.

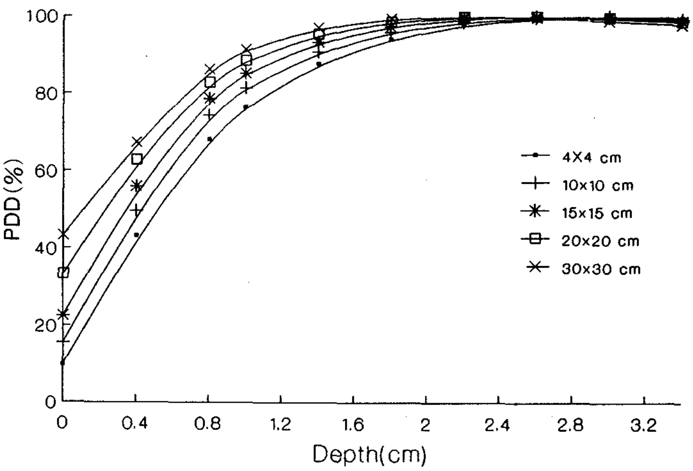

Fig. 2. Bildup curves of 15 MV for various field sizes at measured in polystyrene at 100 cm SSD.

Maximum Ratio. The Tissue-Maximum Ratio over calculated from the measured depth dose data by

$$TMR(d,\ s)=\frac{P(d,\ fs')}{100}\left\{\frac{f+d}{f+d_m}\right\}^2\frac{S_P(s')}{S_P(s'')}$$

where p is percentage depth dose, f is SSD, s' is the $s\cdot f/(f+d)$, s'' is the $s\cdot f/(f+d_m)$ and S_p is the phantom scatter factor[11]. These were calculated from the depth dose data from a normalization depth of 3 cm. The depth of maximum dose is field size dependent. The depth of the maximum dose for the phantom beam in water was found to be from 3.1 cm for $4\times4\ cm^2$ to 2.1 cm for $35\times35\ cm^2$ field sizes at SSD 100 cm. TMR curves for 4, 6, 10, 15 and 20 cm square fields are shown in Fig. 4.

TMR data as a function of depth and field size are shown in Table 3. The calculated data were subsequently compared to TMR measurements in water in Table 4. Note that the maximum differences are less than 2% and greatest at the smaller field sizes and deeper depths. The value of measured and calculated TMR's agree over the clinically important range from 4 to 15 cm depth to within 1%.

3. Beam Flatness and Symmetry

Beam flatness is calculated by comparing equidistant points in both halves of the beam across 80% of the major axis. The results obtained are within 3% for field size of $10\times10\ cm^2$ and larger. Typical dose variation across the central axis is shown in Fig. 5 at a depth[5-7]. of 10 cm for a range

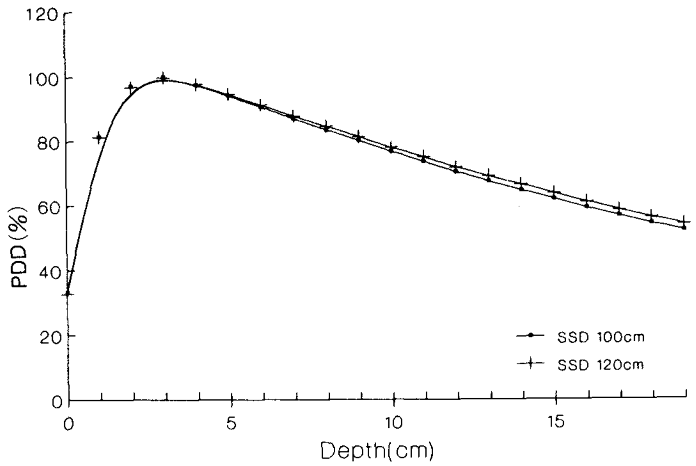

Fig. 3. Central axis Percentage depth dose curves of 15 MV for variation SSD at 10×10 cm field size.

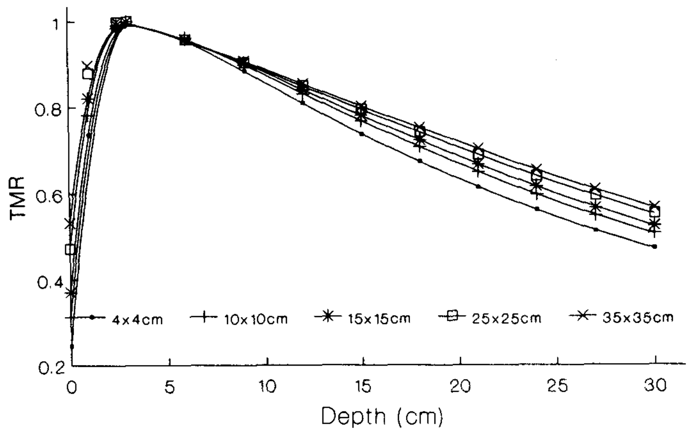

Fig. 4. The TMR curves of 15 MV X-ray for various field sizes at 100 cm SAD.

of field and maximum increase in dose off axis was less than ±3%. But, in case of smaller field than $10\times10\ cm^2$ did exceed 3%.

This measurement was made monthly after the set up the accelerator and showed that there had been no significant change in flatness. Daily measurements of beam flatness showed change of less than 1%.

Symmetry of the radiation fields is calculated by comparing the areas under the two halves of a flatness scan machine specifications puts this at 2% for field sizes of $10\times10\ cm^2$ and larger. Our results did not exceed 1%. Fig 6 shows the variation dose over the whole plane at a depth 3 cm for a field sizes $30\times30\ cm^2$. The dose is normalized to 100 at the center of the field.

A summary of beam flatness and symmetry data is given in Table 5. The beam flatness and symmetry was also measured as a function of collimator angle. The change in flatness and symmetry of X-ray fields with angular position of the Collimator was always within 2%

4. Relative Output Factor

The relative output factor is defined as the ratio of the dose on the central axis at a reference depth for a field size to the dose at the same depth for a reference field size of $10\times10\ cm^2$, at 100 cm SSD.

Table 3. Tissue Maximum Ratio Data for 15MV X-ray SAD = 100cm, Normalized at 3.0cm Depth

Depth (cm)	Field (cm²)									
	4x4	6x6	8x8	10x10	12x12	15x15	20x20	25x25	30x30	35x35
0.0	24.3	26.2	28.8	31.3	33.9	36.9	42.8	47.0	50.1	53.1
1.0	73.5	74.7	76.2	78.2	80.1	82.1	85.3	87.8	88.7	89.6
2.0	94.4	94.6	95.2	95.4	96.1	96.9	97.8	98.5	98.9	99.0
2.5	98.1	98.2	98.4	98.5	98.9	99.2	99.5	99.8	99.9	99.9
3.0	100	100	100	100	100	100	100	100	100	100
4.0	100.1	100.3	100.2	99.6	99.6	99.5	99.1	99.0	98.9	98.9
5.0	98.6	98.6	98.5	98.1	98.0	97.8	97.4	97.3	97.2	97.1
6.0	95.9	96.3	96.3	96.2	96.1	95.9	95.8	95.7	95.7	95.7
7.0	93.4	94.1	94.3	94.0	94.0	94.0	94.0	93.9	93.9	93.9
8.0	90.7	91.6	91.8	91.9	92.0	92.0	92.1	92.2	92.2	92.3
9.0	88.2	89.3	89.7	89.8	90.0	90.2	90.2	90.3	90.4	90.6
10.0	85.4	86.5	87.2	87.5	87.8	88.0	88.3	88.6	88.7	88.9
11.0	83.1	84.2	84.9	85.3	85.7	86.0	86.3	86.6	86.8	87.1
12.0	80.8	81.9	82.7	83.1	83.4	84.0	84.5	84.8	85.1	85.4
13.0	78.5	79.5	80.3	80.9	81.3	81.8	82.4	82.9	83.3	83.6
14.0	76.1	77.2	78.1	78.8	79.3	80.0	80.7	81.2	81.6	82.0
15.0	73.5	74.8	75.9	76.6	77.3	78.0	78.8	79.4	79.9	80.1
16.0	71.3	72.7	73.8	74.5	75.1	75.9	76.9	77.6	78.3	78.6
17.0	69.3	70.6	71.7	72.5	73.2	74.0	75.0	75.8	76.4	76.9
18.0	67.2	68.5	69.7	70.6	71.3	72.3	73.3	74.0	74.7	75.1
19.0	65.2	66.6	67.8	68.7	69.4	70.3	71.5	72.4	73.2	73.6
20.0	63.1	64.6	65.9	66.8	67.4	68.5	69.7	70.6	71.5	71.9
21.0	61.3	62.7	64.0	64.9	65.6	66.7	67.9	68.8	69.7	70.2
22.0	59.8	60.9	62.0	63.1	63.9	65.0	66.3	67.1	68.1	68.5
23.0	57.7	59.1	60.4	61.4	62.2	63.2	64.6	65.5	66.4	67.0
24.0	56.1	57.4	58.6	59.7	60.3	61.6	63.0	63.9	64.7	65.4
25.0	54.2	55.7	57.0	57.9	58.7	59.8	61.4	62.4	63.2	63.9
26.0	52.7	54.0	55.3	56.5	57.1	58.1	59.8	60.7	61.6	62.3
27.0	51.1	52.4	53.7	54.8	55.4	56.6	58.2	59.4	60.2	60.8
28.0	49.7	50.9	52.1	53.2	54.0	55.1	56.8	57.9	58.6	59.3
29.0	48.3	49.5	50.7	51.6	52.4	53.6	55.2	56.4	57.3	57.9
30.0	47.1	48.3	49.5	50.7	51.2	52.4	54.1	55.2	56.0	56.7

The output factors measured in water for a range of square field sizes from 4×4 to 35×35 cm² and for a series of rectangular fields ranging from lengths of 4~35 cm with varying field widths. These measurements were carried out in water at 3.0 cm depth for 15 MV beams. Conventionally, The output factors are measured at the depth of maximum dose[6,10]. Since for high energy photon beams the depth of maximum dose varies with field size, the reference depths of 3.0 cm was used for 15 MV beam. All readings were normalized to a 10×10 cm² field (Fig. 7). The obtained values according to the field size ranged from 0.927 for the field size of 4×4 cm² to 1.087 for 35×35 cm(Table 6).

The relative output were used to determine equivalent square fields for elongated field size. The validity of equivalent square fields for determining the field size factors of rectangular fields was also experimentally verified. The measured factors rectangular fields generally agree within ±1% with the factors computed with equivalent square field.

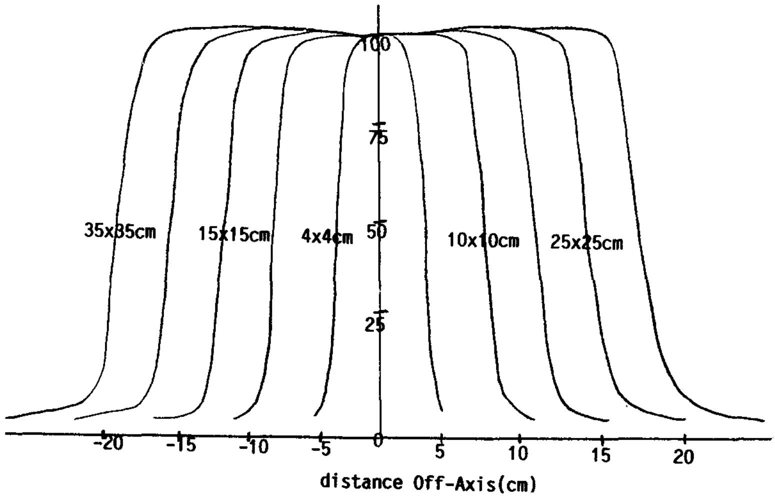

Fig. 5. Transverse axis beam profiles at 10 cm depth and 100 cm SSD for square fields with 4, 10, 15, 25 and 35 cm sides.

Table 4. Percentage Differences in Measured and Calculated Tissue–Maximum Ratios of 15MV X-ray

Depth (cm)	Field size (cm^2)			
	5x5	10x10	20x20	30x30
5.0	0.1	0.2	0.1	0.1
10.0	0.3	0.2	0.2	0.3
15.0	0.5	0.3	0.4	0.5
20.0	0.7	0.5	0.4	0.6
25.0	1.4	0.8	0.6	0.7

$$\text{difference} = \frac{TMR^{calc} - TMR^{meas}}{TMR^{meas}} \times 100\%$$

Table 5. Symmetry and Flatness of 15MV X-ray SSD = 100cm, at a Depth of 10cm

Field Size (cm)	Symmetry (%)	Flatness (%)
4x4	0.15%	5.78%
10x10	0.34%	2.64%
15x15	0.18%	1.72%
20x20	0.47%	1.41%
30x30	0.41%	1.22%

Table 6. Relative Output Factor for 15MV X-ray

Field Size (cm^2)	Output
4x4	0.927
6x6	0.959
8x8	0.983
10x10	1.000
12x12	1.013
15x15	1.033
18x18	1.045
20x20	1.053
25x25	1.068
30x30	1.077
35x35	1.087

Variation of output factors with field size is a complex phenomenon and is very dependent upon the machine. Therefore, experimentaly measured output factors in water are recommended for clinical use. The difference in output factors in water and in air indicates the increased importance of phantom scatter with increasing field sizes[6].

5. Half Value Layer

The measurements were carried out at 100 cm SAD and 5.0 cm depth in polystyrene phantom. Sheets of lead of varying thickness were placed in the accessory tray. The latter is attached to the collimator. Measurements were taken for lead thickness up to Two-half value layer (HVL). The half-value thickness (HVL)[8,9,13] of lead is 13 mm, which corresponds to an attenuation coefficient of 0.053 mm^{-1}. The percentage transmission in a

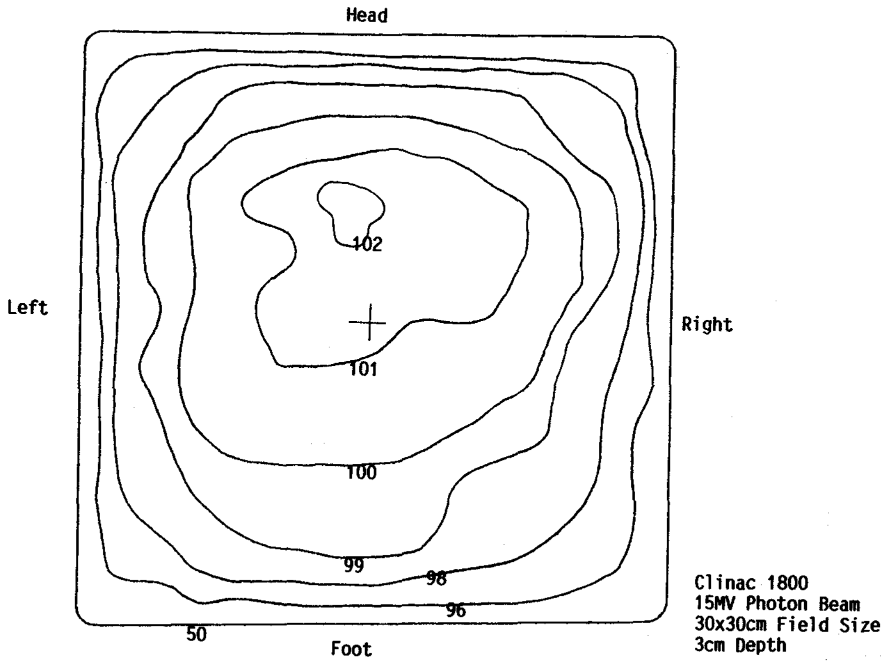

Fig. 6. Dose variation in a plane perpendicular to the central axis at a depth 3 cm in polystyrene at 100 cm SSD.

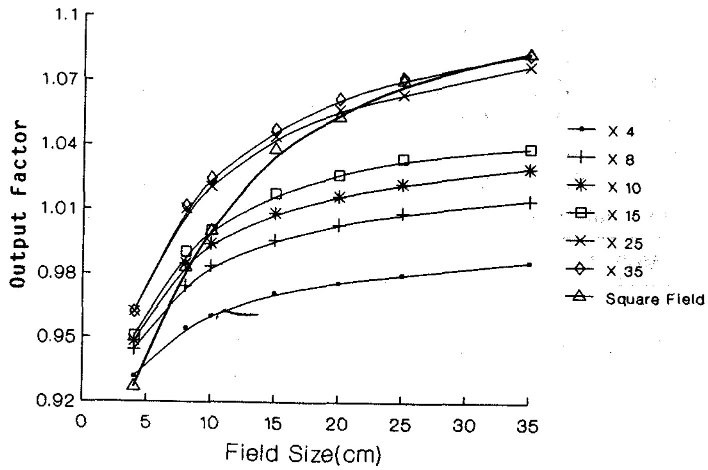

Fig. 7. Relative output variation factor as a function of field length, normalized to a 10×10 cm field at 100 cm SSD.

given thickness of lead changed by 1% when the field size was change from 5×5 to 20×20 cm^2 for the 15 MV beam.

For Lipowitz metal (brand name, Cerrobend) was measured in the manner described above. The HVL of Cerrobend were found to be 15.5 mm. which corresponds to an attenuation coefficient of 0.045 mm^{-1}. The transmission through 8 cm of cerrobend was measured. This was found to be 3.4% for the 15 MV beam. This thickness is considered sufficient to use on patient shielding.

6. Wedge and Tray Factors

When a wedge filter is used to modify the dose distribution in a beam of megavoltage X-rays, the beam intensity is reduced. The wedge factor is defined as the ratio of output at depth with the wedge in place to that without the wedge. Measurements were performed at 100 cm SSD in a water and in a polystyrene phantom at the depth of 10 cm[10]. The axis of the chamber was perpendicular to the direction of wedging. Measurements were made of electrometer reading per 100 monitor units, with several readings being done alternately with and without wedge.

The measurements were repeated with the wedge rotated through 180°, and an average ratio calculated. Four wedges are provided with the machine (15°, 30°, 45°, and 60°). These are made of stainless steel.

They are usable for field sizes up to 20×35 cm^2 except for the 60° wedge which may be used up to 17×35 cm^2 field wedge. The wedge transmission field factors were measured and are reported in Table 7. The Acryle blocking tray is being used to support irreqular field blocks for patient treatments. It was determined by measuring the central axis depth dose for a range of field sizes with and without the blocking tray. The blocking tray factor was measured 0.976 at 10×10 cm^2 field size.

DISCUSSION

The ratio of ionizations at 10 cm and 20 cm depth in water, for a 10×10 cm^2 field at 100 cm SAD, gives the nominal accelerating potential on the Clinac 1800 15 MV. The measured ionization ration of TMR 20/10 was obtained with 0.763 ± 0.002 which corresponds to a nominal accelerating potential of 14.2 ± 0.5 MV for this photon beam. We have checked other method of beam quality[4] according to BJR supplement 11 and 17, The equation is

Table 7. The Wedge Transmission Factors for 15MV X-ray

Wedge angle	Wedge factor
15°	0.825
30°	0.699
45°	0.560
60°	0.457

$d = 26.09 \log Q + 46.78$ (for $4 \leq Q \leq 45$)
solving explicity for the other variable;
$Q = 10^{(d-46.78)/26.07}$

where d is the percentage depth dose at 10 cm for a 10 cm square field and an SSD of 100 cm Q is the quality in megavolts. The percentage depth dose at 10 cm for a 10 cm square field is 76.8%. The beam quality is 14.2 MV for this photon beam. The representation of BJR supplement 11 data, reflects rather well the various manufacturers' published specifications of 62~63% for 4 MV, 67% for 6 MV, 73% for 10 MV, 77% for 15 MV, approximately 79% for 18 MV and 83% for 24 MV.

And also, Manufacturers usually specify both Dmax and 10 cm depth dose to characterize the penetrative quality of their photon beam. The equation is

$Dmax = 3.775 \log Q - 1.378$ (for $4 \leq Q \leq 45$)

Where Dmax is the depth of dose maximum in centimetres for a 10 cm square field and an SSD of 100 cm and Q is the stated quality of the beam in megavolts. According to the data of Q is 14.2 MV, therefore Dmax is 3.0 cm. The measured data is also 3.0 cm.

Although in principal Dmax could be used to estimate beam quality, depth dose provides a more reliable determination because it can be measured more precisely than Dmax and is less influenced by variations in electron contamination.

The percentage depth doses in general increase with field size for a fixed depth. However, There is a decrease in percentage depth dose with increasing field size in the depth region from 4 cm to 7 cm for fields greater than 8×8 cm.

As an estimate of surface dose we use the value of the 0.1 cm^3 ion chamber and the values range from 25.9% for the 4 cm square field to 53.2% for the 30 cm square field. There were a big difference between the value of the 0.1 cm^3 chamber and the value of the 30~404 parallel plate chamber.

The physical characteristics of the 15 MV photon beams were intermediate between that of 10 MV and 21 MV X-rays. The nominal accelerating potential of the this photon beams could be determined with 14.2 ± 0.5 MV. The depth of maximum dose was 3.0 cm for 10×10 cm^2 field size.

The depth of maximum dose has been showed the variation from d_{max} of 2.1 cm for large field to that of 3.1 cm for amall field. As expected, the depth of maximum dose shifts towards the surface as the field size increases.

The surface dose showed 15.5% for a field size

10×10 cm² 9.8% and 43.3% for 4×4 cm² and 30×30 cm² field sizeds, respectively. As the field size increases, the surface dose increases for the 15 MV photon beams. The depth dose for a 10×10 cm² field size at 10 cm depth and 100 cm SSD was 76.8%. The depth of 80% dose and 50% dose for a 10×10 cm² field at 100 cm SSD were 9.1±0.1 cm and 19.9±0.2 cm, respectively.

The value of measured and calculated TMR's agree over the clinically important range from 4 to 15 cm depth to within 1%.

The symmetry and flatness were 0.73% and 2.72% for 10×10 cm² field size. The relative output factors ranged 0.927 for 4×4 cm² field size to 1.087 for 35×35 cm² field size. The Half value thickness (HVL) of lead and Cerrobend were found to be 13 mm and 15.5 mm, respectively.

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= 국문초록 =

CLINAC 1800 선형가속기의 15 MV X-선의 특성

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국내에서 처음으로 사용되는 CLINAC 1800에서 발생된 15 MV X-선의 특성을 구하기 위하여 3 Dimensional water Phantom Dosimetry system)를 이용하여 방사선 치료에 근간이 되는 심부선량 백분율(PDD), 최대 조직 비율(TMR), 편평도(beam profile), 대칭도, Wedge 인자 등을 측정하였고 선량계산을 위하여 출력인자들을 구하였다.

1. 선축상 최대치 지점(Dmax)은 SSD 100 cm일때 조사면이 10×10 cm²에서 3.0±0.1 cm이였고 4×4 cm², 35×35 cm²에서 각각 3.1±0.1 cm, 2.2±0.1 cm으로 조사면이 넓어지면서 측정치가 표면에 가까워지는 결과를 보였다.

2. 조직표면 선량(Surface Dose)는 SSD 100 cm일때 조사면이 10×10 cm²에서 15.5%이였고 4×4 cm² 35×35 cm²에서 각각 9.8%, 51.2%로 조사면이 넓어지면서 표면 선량은 증가하는 결과를 보였다.

3. 심부선량 백분율(PDD)은 SSD 100 cm에서 측정하였고 조사면이 10×10 cm²이고 10 cm depth에서 76.8%이였고 80%, 50% 선량의 깊이는 각각 9.1±0.1 cm, 19.9±0.2 cm으로 측정되었다.

4. 최대조직비율(TMR)은 심부선량 백분율(PDD)로부터 계산하였고 측정값과의 차이는 10×10 cm² 조사면에서 평균 1% 이내의 오차를 보였다.

5. 대칭도(symmetry)와 편평도(flatness)는 조사면 10×10 cm²일때 각각 0.73%, 2.72%이였다.

6. 출력인자(output factor)는 10×10 cm² 기준 조사면에서 흡수선량을 1로 하였을때 4×4 cm², 35×35 cm² 조사면에서는 각각 0.927, 1.087로 측정되었는데 조사면이 증가할수록 흡수량이 증가하는 결과를 보였다.

7. Wedge factor는 15° 30° 45° 60°를 10 cm 깊이에서 측정하였는데 0.825, 0.699, 0.560, 0.457로 각각 측정되었고 아크릴 6.4 mm Tray의 투과율은 0.976이였다.

8. 15 MV X-선에 의한 납벽층의 반가층 두께는 13 mm였고 Cerrobend의 반가층은 15.5 mm으로 측정되었다.