Long Term Quality Measurements During Clinical Operation of Limex Low Energy Medical Accelerator

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Abstract

The 4 MeV X-ray beam of Limex accelerator has been applied at Warsaw Cancer Centre since 1986. Prior to clinical use, measurements of beam distributions, including beam quality and output dose, were performed. Its results were compared with the beam distributions of Theratron 780C Cobalt-60 unit. Since 1986, periodical quality measurements have been continuously conducted. Five years experience of Limex exploitation indicates that the dose distributions have been time-stable and agreeable for radiotherapy.

1. INTRODUCTION

Limex 4 Mev electron linear accelerator is the modern radiation unit designed at the Soltan Institute for Nuclear Studies according to the clinical requirements [1-6]. The Limex employs a standing wave accelerating structure working in 3 GHz frequency band. Accelerated and focused electron beam generates high intensity X-rays on tungsten target. The photon beam is shaped into a rectangular field with dual collimation system: primary fixed collimator and the secondary one - two pairs of movable jaws. The dose distribution is shaped by the flattening filter. The irradiation of the patient is monitored by dual independent dosimetric system which controls dose-rate, dose, and treatment time. The radiation head with accelerating structure, r.f. generator and modulator is located on the gantry which can rotate around the isocentre axis. Fixed angle or arc therapy modes of operation can be selected.

Table 1: Basic specifications of Limex accelerator.

Energy of accelerated electrons	4 MeV
e^-/X target	tungsten
Focal spot size	< 3 mm
Accelerating structure	S band, $\pi/2$ mode
Dose rate at the isocentre	0.5, 1, 2 Gy/min
Source to isocentre distance	0.8 m
Field size	4x4 - 22x28 cm
Gantry rotation angle	365°
Collimator rotation	-65° - +65°
Microwave generator	2 MW pulse magnetron

2. MATERIAL AND METHODS

2.1. The initial dosimetry of Limex beam.

The initial dosimetry of Limex X-ray beam served to acquire full data necessary to radiotherapy planning, i.e. set of percentage depth doses (*PDD*), beam profiles and the full set of isodose curves. The build-up region and skin dose measurements were performed. The effect of field size on penumbra for various depths in the phantom was studied. The set of relative output doses normalized to 10x10 cm field dose at the depth of dose maximum (d_{max}) in water phantom was evaluated. The beam quality factor J_{10}/J_{20} was determined.

2.2. The periodical dosimetry.

The periodical dosimetry comprises: output dose and beam quality checks, *PDD* and profile measurements. Output checks were conducted every day from the clinical start of the accelerator in July 86 by six months. No output adjustments were made in this period. Since January 87 output dose rate has been checked once a week and adjusted if its value run out of range 2 Gy/min ± 2 cGy/min. The output was occasionally checked before and after patient irradiations. Apart from phantom measurements the output reproducibility was examined in air for various accelerator angle positions. Beam quality factor J_{10}/J_{20} has been determined every 3 months. Beam profiles for a few field sizes at the depth of 2, 5, 10 cm in water phantom are measured (and adjusted if necessary) every 3 months in order to determine beam flatness and its symmetry. Beam geometry parameters including light simulation, field size accuracy and isocentre positioning are also periodically checked.

2.3. Instrumentation.

The following instrumentation was used in the measurements:

- dosimeters: Ionex 2500/3 (Nuclear Enterprises), Farmer 2570 (Nuclear Enterprises)
- cylindrical chambers: types 2571, 2581 (Nuclear Enterprises)
- plane parallel chamber: type 2534 (Nuclear Enterprises)

- radiation field analyzer RFA-3 Therados (Scanditronix) equipped with ion chambers and silicon diodes
- water phantoms: RFA-3 (Scanditronix), 2545/A (Nuclear Enterprises)
- solid phantoms: PMMA block, PMMA plates
- films: Kodak Omat XV
- film densitometer RFA-3.

3. RESULTS AND DISCUSSION

3.1. Comparison of some dosimetry parameters of Limex X-ray beam with those of Theratron780C Cobalt-60 unit.

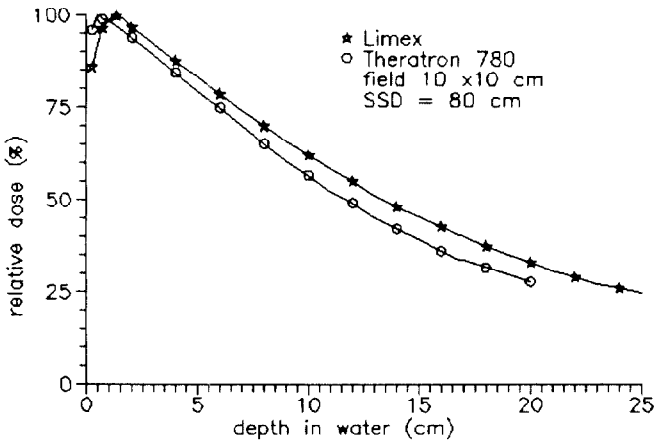

Fig.1. Percentage depth dose for Limex and Theratron 780; field 10x10 cm, SSD=80 cm.

The *PDD* for 10x10 cm field (*SSD*=80 cm) is shown in Fig. 1 for Limex and Theratron 780C beams. The *PDD* at 10 cm is 62% for Limex and 56% for Theratron beam.

In Fig. 2 Limex beam profile for 20x20 cm field at 10 cm depth is compared with that of Co-60 beam. For the maximum field size of Limex (22x28 cm) the beam flatness is 0.8% at the depth of 10 cm (3% allowed [3 - 6]).

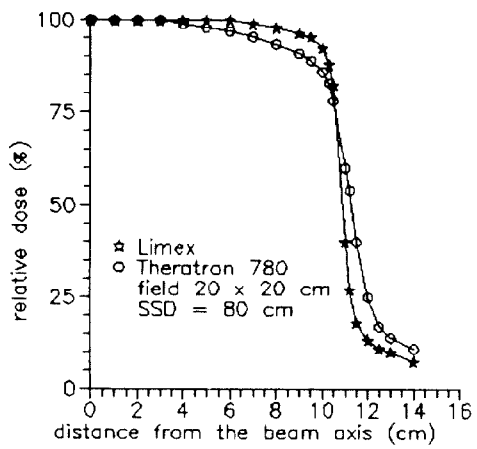

Fig.2. Comparison of Limex and Theratron 780 beam profiles ; field20x20cm,

In Fig. 3 isodose curves of Limex and Theratron are compared for 10x10 cm field at *SSD*=80 cm. *PDD* at the build-up region (10x10 cm, *SSD*=80 cm) for

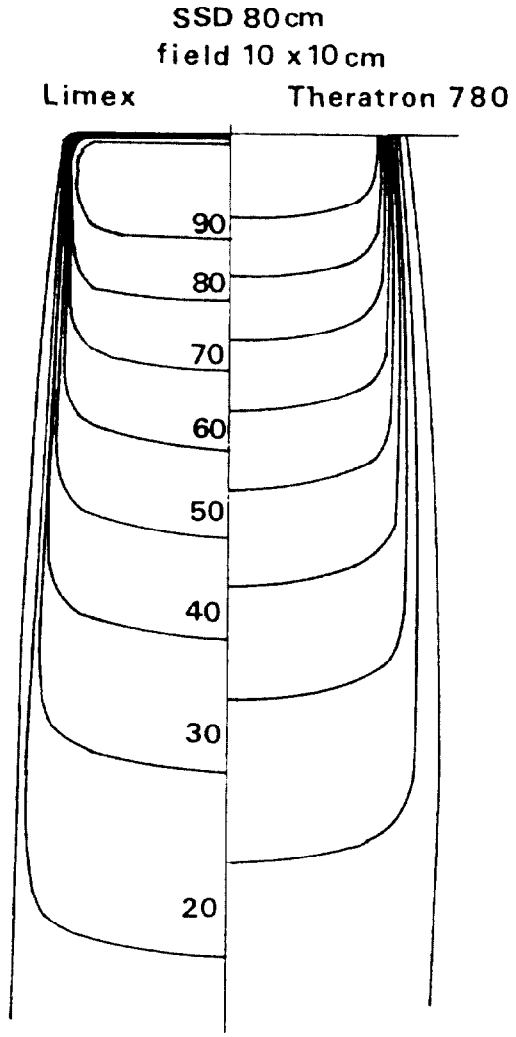

Fig.3. Comparison of isodose curves for Limex and Theratron 780; field 10x10 cm, SSD=80 cm.

Limex and Theratron 780C is shown in Fig. 4. The depth of dose maximum is d_{max} = 1.2 g/cm^2 for Limex and d_{max} = 0.4 g/cm^2 for Co-60 beam. Theskin doses (corrected for non-zero chamber volume) increase from 16% (5x5 cm field) to 33% (20x20 cm) for Limex and from 22% (5x5 cm) to 47% (20x x20cm) for Theratron.

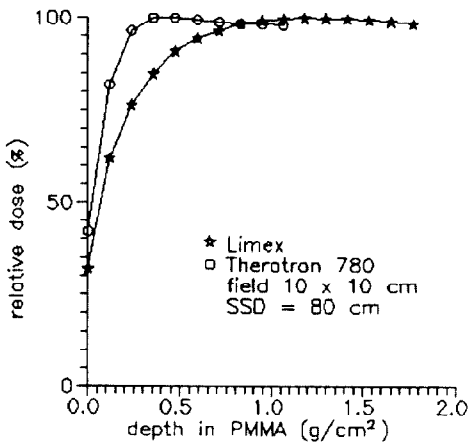

Fig. 4. Percentage depth dose in the build-up region for Limex and Theratron 780; field10x10cm, SSD=80 cm.

The penumbra widths for 5x5 - 20x20 cm fields range for Limex: 5 - 6.5 mm at the depth of 3 cm and 8 - 12 mm at 10 cm and: 8 - 10 mm at 3 cm and 10 - 14 mm at 10 cm for Theratron.

The absolute dose rate at the depth of d_{max} = 1.2 cm for 10x10 cm field at SSD=80 cm is kept at the value of 2 Gy/min. The relative output dose ranges from 95% (4x4 cm field) to 107% (22x28 cm). The initial beam quality factor was equal J_{10}/J_{20} = 1.86 (corresponding to 4 MeV energy of electrons striking the target).

3.2. Periodical dosimetry of Limex beam 1986 - 1991.

In 1986, output dose checks were made every day without any dose rate adjustments. Their results indicated that the average dose rate was 2.045 Gy/min with the mean square error of 1.0%. The temperature and pressure corrections were applied. Since 1987, output dose was weekly checked and adjusted (if its value was out of range 2 Gy ± 2 cGy). The resulting average dose rate was 2.008 Gy/min with the mean square error of 1.9%. The readings were always taken before adjustments and corrected for temperature and pressure. Output dose measurements were carried out with a ventilated cylindrical chamber placed in water phantom at the reference depth. Monitor units number was kept constant during the measurements. The monitoring chamber built-in to the accelerator head is non-ventilated and not equipped with a temperature correction system. It was observed that the measured dose relative to the monitor dose violently increased at very low atmospheric pressure (about 970 hPa). This effect revealed that the monitoring chamber was not air-tight. In 1986-1991 the ratio of the average dose rate corrected for pressure and temperature to that corrected only for temperature was 1.011.

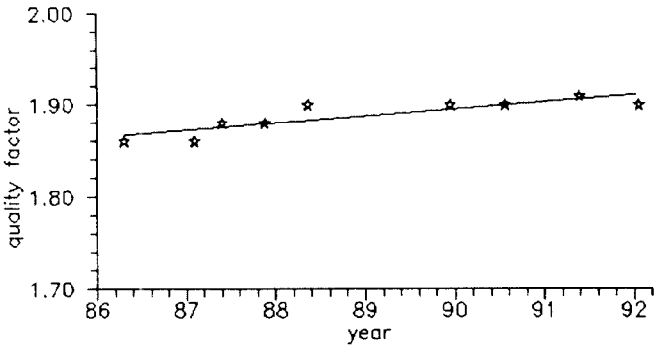

Fig.5. The quality factor of Limex beam.

The output dose was occasionally tested before and after patients' irradiations. Results of these tests indicated that the measured dose relative to the monitor dose increased by 0.4% - 1.9% after patients compared to that before patients. This effect is due to temperature growth in the accelerator head relative to ambient temperature.

Output dose reproducibility for various gantry angles remained within ± 1% of the average dose.

The beam quality factor J_{10}/J_{20} was slowly increasing (see Fig. 5) from its initial value of 1.86 (1986, May) to 1.90 (1991, December). This only slightly effects *PDD* and shapes of isodose curves. No corrections were applied for this effect to the therapy planning system. Beam symmetry, flatness and beam geometry parameters checked in the period of 1986-1991 remained inside the acceptability ranges, as recommended by IAEA, NCRP, and IEC [3, 4, 5].

4. CONCLUSIONS

It can be noted that Limex X-ray dose distributions have been time-stable and agreeable for radiotherapy.

The tests of beam geometry, light simulation and isocentre positioning have demonstrated, that after five years of exploitation these parameters agree with international recommendations [4, 5].

An experience acquired during long time clinical operation allowed to derive suggestions, which are useful for design of new model of the accelerator: new solution of the collimator, better arrangement of some accelerator parts in rotating gantry and introducing a compensation system of pressure and temperature in the monitoring chamber.

5. REFERENCES

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