

Tertiary collimator system for stereotactic radiosurgery with linear accelerator

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In the last decade, stereotactic radiosurgery (SRS) with linear accelerator (linac) has become an important irradiation technique for a variety of malignant and benign intracranial lesions. Although there exist some other radiosurgery techniques, linac based SRS meets the requirements needed for SRS with low cost modifications. One of the most important additional parts of the equipment is tertiary collimator system which can be attached onto the linac head. We designed and built such system that can be easily fixed onto linac PHILIPS SL – 75/5 with 5 MV photon energy. In our department, we already use this linac for conventional radiation therapy. Our tertiary collimator system meets all the requirements important for this special modality of radiation therapy. It allows fine centering of the system and has ten various collimators with divergent circular openings having a nominal field diameter ranging from 1.0 cm to 4.0 cm at the isocenter. The accuracy of the system was checked by exposing x – ray films at various gantry positions, and recording misalignment of the beams. The width of penumbra was determined using two different dosimetry techniques (film dosimetry and diode measurements).

Key words: radiosurgery – instrumentation; brain disease – surgery; particle accelerators

Introduction

Stereotactic radiosurgery (SRS) is a focal brain irradiation technique which delivers a high dose of ionizing radiation to stereotactically localized small intracranial lesions in a single session. SRS is a nonstandard radiation therapy technique which was introduced in 1951 by Leksell¹ and is currently performed with three basic modalities: with protons, ⁶⁰Co Gamma knife and with megavolt-

age x – ray beams from linear accelerators. As the first two modalities are extremely expensive and are dedicated for SRS alone, in 1980s many centers have introduced linac based SRS.²⁻⁷

One of the most important modifications, among many others, is to design and build tertiary collimator system for delivering highly collimated linac beams to the target. Many different approaches were taken in the past.^{8,9}

Conventional collimators which are part of the head of linac, are inadequate for SRS because they can be set up only for rectangular fields and are too far from the isocenter

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which produces unacceptably large penumbra.

The aim of our project was to design and build a rigid, low cost, yet very precise tertiary collimator system, which can be simply and quickly attached onto the head of our 5 MV PHILIPS – 75/5 linac, presently used in our department for conventional radiation therapy.

Materials and methods

While designing and assembling our tertiary collimator system (the system was constructed at the Institute for Electronics and Vacuum Technique, Ljubljana, Slovenia), we had to follow many important requirements such as: stability of the system during rotation of the gantry, short distance from tertiary collimators to the isocenter, easy and reproducible attachment of the system onto the head of linac, possibility of precise positioning (centering) of the system, various field diameters at the isocenter and high attenuation of the primary x-ray beam in the collimator walls.

We followed these requirements in designing and assembling of our tertiary collimator system which is constructed of an aluminium plate with a precise mechanical system in its center and a steel holder for various collimator inserts (Figure 1,2). The position of the collimator holder, which moves perpendicularly to the beam axis in two directions, is set by two micrometer regulators. These regulators enable precise and continuous movement of the holder which can be reproduced with precision of 0.1 mm. After reaching a desired position, we can fix both axes, defining the plane, orthogonal to the beam axis, with two large steel regulators to prevent any movement of the collimator holder relative to the rest of the system. The system itself is attached onto the linac head as tight as possible in order to prevent any undesired move-

ment of the whole system during gantry rotation.

Additionally, we made ten different collimators – inserts with circular openings which can be inserted into the steel collimator holder (Figure 3). Collimators are made of lead and openings are continuously tapered to match the beam divergence to minimize the penumbra. The distance from the end of the collimator to the isocenter is 28.3 cm which further minimizes the width of penumbra. Each collimator is cylindrically shaped, having outer diameter of 6 cm and length of 12 cm. Nominal field diameters defined at the isocenter are: 1.0 cm, 1.25 cm, 1.5 cm, 1.75 cm, 2.0 cm, 2.25 cm, 2.5 cm, 3.0 cm, 3.5 cm and 4.0 cm. A diameter of 6 cm is sufficient to fix adjustable collimator jaws (primary and secondary) to a field size

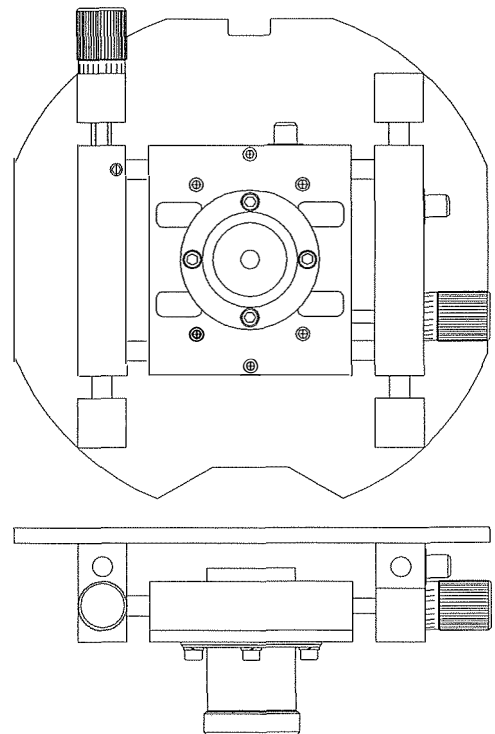


Figure 1. Schematic drawings of tertiary collimator system: a) beam axis view and b) side view, perpendicular to the beam axis.

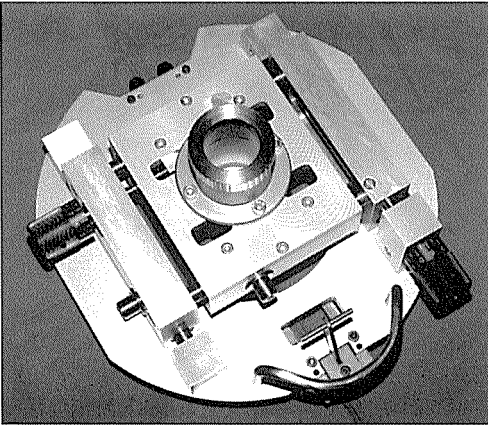


Figure 2. Tertiary collimator system.

$5 \times 5 \text{ cm}^2$ at the isocenter during irradiation. On the other hand, the length of 12 cm in the direction of beam axis is large enough to attenuate primary x-ray beam to about 1% compared to the output of an unblocked 5 MV beam.

Beam penumbra was measured by scanning beam profiles for each collimator using a) Multidata film densitometer, Kodak X-Omat V radiographic films and a phantom made of white polystyren and b) Scanditronix p-type silicon diodes and Multidata two dimensional water phantom.

Results

After having centered precisely the collimator system, the alignment of the collimator was checked with lasers fixed to the ceiling and side-walls and optical field center and using radiographic film (Kodak X-Omat V).

First, we placed the film horizontally at the isocenter and exposed it to two parallel opposed beams with gantry angle at 0° and 180° (Figure 4.a); then we placed second film vertically through the isocenter and again exposed it to two parallel opposed beams with gantry angle at 90° and 270° (Figure 4.b). Similar procedure is used in Montreal General Hospital, Canada (McGill University) and

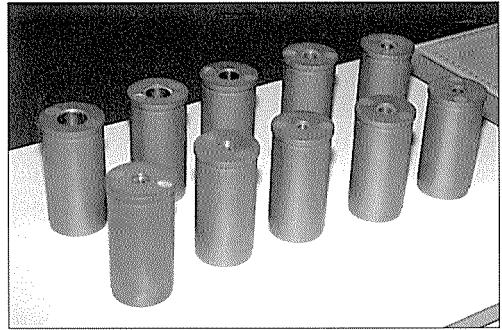


Figure 3. Ten collimators with nominal field diameters at the isocenter: 1.0 cm, 1.25 cm, 1.5 cm, 1.75 cm, 2.0 cm, 2.25 cm, 2.5 cm, 3.0 cm, 3.5 cm and 4.0 cm. Collimators have outer diameter of 6 cm and a length of 12 cm.

in some other centers.^{8,10,11}

Conformity of each pair of film exposures is a measure for collimator alignment. In our case, we estimate the shift of one exposure pattern with respect to the other to be less than 0.5 mm (in both cases) and that is well within our tolerance level (1.0 mm).

The width of penumbra (i.e. distance between 20% and 80% isodose line) measurements also yielded very good results.¹² In the first case (film scanning) the width of penumbra ranged from 2.5 mm for 1.0 cm collimator to 3.1 mm for 4.0 cm collimator, while in the case of diode measurements the width of penumbra ranged from 2.6 mm for 1.0 cm collimator to 3.2 mm for 4.0 cm collimator.

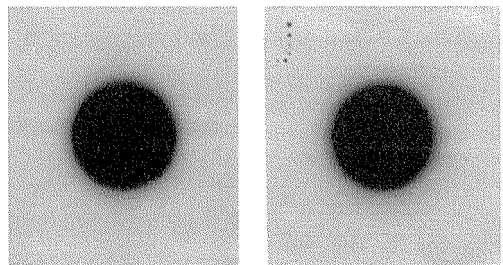


Figure 4. Verification films illustrating collimator alignment. Collimator diameter is 2.5 cm, film is placed at the isocenter, perpendicularly to the beam. Figure a) shows the image for two parallel - opposed beams (gantry angles: 0° and 180°) and Figure b) shows the image for two parallel - opposed beams (gantry angles: 90° and 270°).

Conclusions

The tertiary collimator system which we designed and built for stereotactic radiosurgery with linear accelerator has very good mechanical and dosimetric properties and can be used for this special radiation therapy technique. Easy handling and relative low cost of production furthermore confirm that our work was successful.

Acknowledgements

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