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# Development of a prototype stereotactic collimation assembly for Neptun 10 PC linac

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**ABSTRACT**

**Background:** A set of hardware stereotactic radiosurgery is designed and constructed. The scope of this article is to describe how we have designed and developed stereotactic collimation assembly for a 9 MV Neptun 10 PC linac.

**Materials and methods:** One collimator holder and six collimators were made, with their radiation field diameter between 12.5 mm to 25 mm at isocenter level. Beam data, such as depth dose percent, off axis ratio and output factor of the collimators were measured. Isocentric accuracy and dose delivery, accuracy tests were also performed using locally made isocentric alignment control device, target simulator and plexiglass phantom.

**Results:** Average isocenter shifts resulting from gantry and couch motion were respectively 1.5 mm and 2 mm. Simulating a stereotactic radiosurgery with the help of a plexiglass phantom showed less than one percent radiation leakage to critical organs such as eyes and thyroid.

**Conclusion:** Stereotactic collimation assembly in conjunction with the rest of constructed equipments can be employed to set up SRS treatment, provided safety and to compensate operations are taken into account. *Iran. J. Radiat. Res., 2004; 2 (3): 135-140*

***Keywords:*** *Stereotactic radiosurgery, auxiliary collimator, linear accelerator, isocenter, phantom.*

## INTRODUCTION

The term "stereotactic radiosurgery" was introduced by the Swedish neurosurgeon, Lars Leksell, in 1951 to describe a new method for treatment of diseased or dysfunchional tissue with a single large dose of radiation delivered stereotactically by focused narrow beam (Leksell 1951).

Stereotactic radiosurgery requires small field sizes ranging from 5 mm to 40 mm which normally can not be produced by conventional linear acclerators. For this reason, a series of auxiliary collimators are necessary. Neptun 10 PC made by Andrzej Soltan institute with a 9 MV X-linac ray beam is not widely used linac, and this attempt has been one of first trials to design and equip this machine with stereotactic radiosurgery system. Stereotactic collimation assembly is only a part of a complete set of devices we have made to set up SRS system. Minimum and maximum field diameters obtainable by the collimators ranged from 12.5 mm to 25 mm at isocenter level. An isocentric alignment control device has been added to collimator assembly to check overall isocentric accuracy of the set up.

Dose verification and radiation leakage tests were performed using an especially designed phantom along with TLD cubes ($1\times1\times1 mm^3$).

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## MATERIALS AND METHODS

### *Linac*

A Neptun 10 PC linac with 9 MV X-rays is used. Isocentric accuracy of this linac as specified by the manufacturer is 2 mm. It is equipped with an arc therapy system which enables X-ray irradiation during the gantry rotation in a chosen angular motion. X-ray beam intensity is regulated within the range of 1-8 cGy/deg. Source to isocenter distance is adjusted to 1000 mm and secondary collimator base has been at 442 mm from isocenter.

### *Metals and alloy*

All parts of collimator assembly are made from aluminium except for the collimators, core. Aluminium is a light strong metal, therefore its application does not impose intolerable weight to gantry. The core of collimator is made of a specially composed alloy namely cerrobend, consisting of 15.5% Sn, 52.5% Bi and 33% Pb. It's melting point is 94°C.

### *Collimator designing*

AutoCAD software was used to draw plans of individual parts of stereotactic radiosurgery system. This software is a suitable and powerful tool for industrial designing. AutoCAD allows to imagine each part individually and in combination with other parts in three dimensions.

### *Components description*

Collimator assembly consists of two major parts: collimator holder and auxiliary collimators. Collimator holder by itself is composed of the following parts: One rectangular tray to attach the system to the gantry; Two sliding plates; Two micrometers; Two handles and; One attachment block for affixing alignment control device (figure 1).

### *The tray*

It is made of aluminium. This is the part of assembly which is attached to the head of linac's gantry. We designed and made this part according to the shape and size of built in frame of gantry, used for attachment of conventional plexiglass tray holding shielding blocks. There is a central hole on the rectangular tray to allow incident X-ray to pass through it.

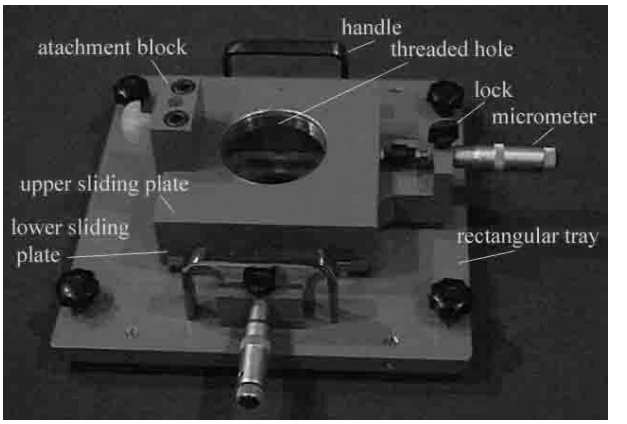



**Figure 1.** Collimator Holder used for attachmant of stereoatactic collimator to gantry's head.

### *Sliding plates*

They are made of aluminium. They are used to move the collimator until the central axis of the beam coincides with the central axis of the auxiliary collimators. The upper sliding plate is connected to the lower sliding plate by a special guide way system (made of brass) to enable accurate adjustment of collimators. A threaded hole has been made at the center of lower sliding plate to accommodate auxiliary collimators. This mechanism should be so accurately designed to avoid any lateral and vertical displacement of the collimator.

### *Micrometers*

They allow fine adjustment of the two sliding plates. Both ends of micrometers are attached to sliding plates by a floating joint. Both micrometers are equipped with locking system to allow collimators to be fixed at a correct position.

### *Two handles made of steel*

They are mounted at two apposite sides of the aluminium tray. The handles provide easy movement and installation of the assembly.

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***Attachment block***

It is placed on lower sliding plate allowing isocentric alignment control device be connected to collimator assembly. Isocentric alignment control device consists of a vertical bar and two film holder rings.

***Auxiliary stereotactic collimators***

They are made of external aluminium shells and a cerrobend core. The overall height of collimator shell is 130 mm which accommodates a central core of cerrobend 110 mm in height. It's external diameter in non threaded part is 100 mm which allows an 85 mm (in diameter) cerrobend core to be fitted inside it (figure 2). Based on actual measurement of secondary collimator base to isocenter, proximal and distal ends of auxiliary collimator to isocenter distances and finally desired field diameters at isocenter level, dimensions of holes at proximal and distal planes of stereotactic collimators were determined. The lower part of each collimator has an aluminium cap which is fixed to the body of collimator. The internal diverging canal is initially obtained by introducing a steel tube (of exact shape and dimension needed to get the specified diameter) inside the aluminium shell and then filling collimator with melted alloy.




**Figure 2.** Stereotactic collimator used for limiting radiation fields to desired dimensions.

The steel tube is extracted after nearly one month, when the alloy has got completely cooled. Cerrobend height of 11 cm, as we have measured is enough to reach 0.5% of primary output at build up underneath the shielded area.

***Measurement of beam data***

Beam data such as percent depth dose, off-axis ratio and output factor were measured for constructed collimators. Lateral electronic disequilibrium is compromised when X-ray energy is so high or the beam radius is so small that the latter becomes comparable to the maximum electron range (Rice *et al.* 1987). This affects the transverse beam profile as well as the absorbed dose on the central axis as such that led Chiergo *et al.* to conclude "optimum energy for small field clinical applications of X-ray beam is 4-6 MV" (Chiergo *et al.* 1988). As our photon energy was 9 MV we should have paid more attention to this issue. The size of detector is primary parameter to be considered in small field dosimetry and compensating lateral electronic disequilibrium is the next parameter playing an important rule in higher energy photon. Photon field detector, Hi-Psi diode, made by Scanditronix system is an excellent choice in relative field analysis as well as out put factor measurement (Somiglia 1999).

For high doped p-type silicon detector chip (Hi-Psi) active region size (in mm) perpendicular and parallel to beam direction are respectively 2.5 and 0.06 mm (Somiglia 1999). According to Hartman's rule (Hartman *et al.* 1993), since our minimum size of radiation field at isocenter level was 12.5 mm, these sizes were ideal for our purpose.

Percent depth dose was measured using diode detector from depth of 250 mm to surface of water phantom. Figure 3 depicts variation of percent depth dose versus depth for developed collimators.

OAR values were measured at depth of 70 mm across radiation field using diode detector. Figure 4 shows off axis profile of various collimator sizes.

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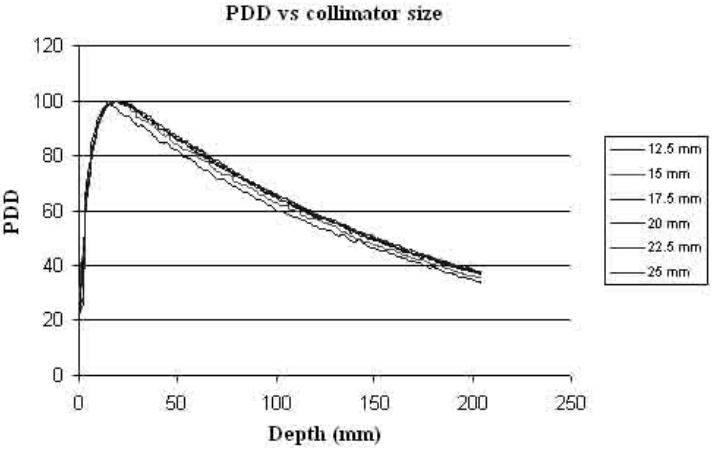



**Figure 3.** PDD variation versus depth in water from depth of 250 mm to surface.

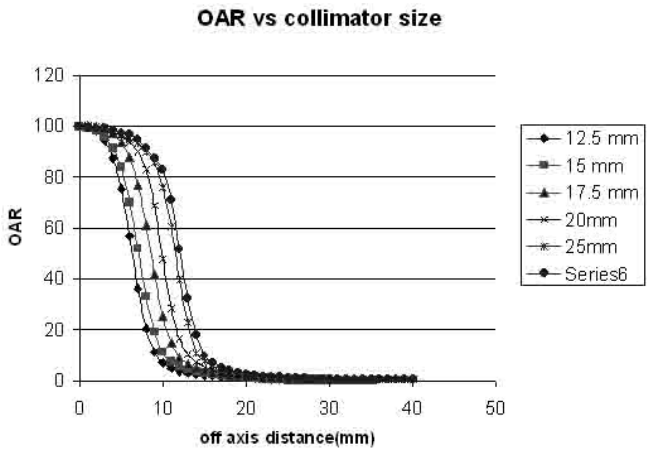



**Figure 4.** Off axis curves for 12.5 mm to 25 mm collimators at depth of 70 mm.

Out put factors were measured at $d_{max}$ of calibration field for various collimators using diode detector connected to Scanditronix Welhoffer electrometer. Variation of out put factor as a function of radiation fields diameter is shown in figure 5.

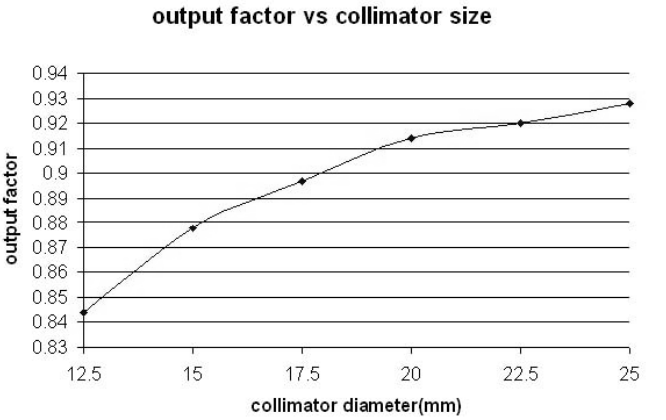



**Figure 5.** Out put factor versus sizes of stereotactic collimators.

## Acceptance test

### *Isocentric alignment control*

One of the first requirements for stereotactic radiosurgery treatment is that central axis of the auxiliary collimator, corresponding to the central X-ray beam passes through the isocenter of linac. In stereotactic radiosurgery there are two constraining factors; small radiation field and high delivered dose, which minimizes tolerable errors (AAPM 1995).

We have designed a special target simulator to be connected to docking device of couch based system. Target simulator consists of a

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plexiglass plate in which a small steel ball is embedded. Alignment control device was attached to collimator by means of a vertical bar. Then a verification film was placed between two rings at the end of vertical bar to keep the film in a fixed position. As the next step target simulator was mounted on docking device through four coupling. Then small steel ball of target simulator was aligned at the best-compromised isocenter. Finally, radiographs were taken at various combination of gantry and couch angles.

Radiographs were developed at appropriate conditions, any shift of steel ball's image from center of radiation field was measured (figure 6).

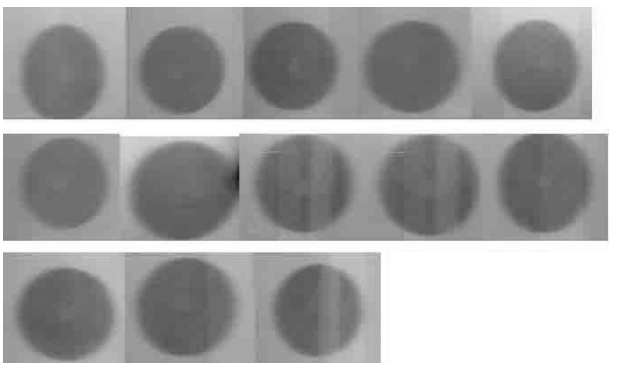


**Figure 6.** Radiographs taken at various gantry and couch angles.

### *Beam size at isocenter plane*

Full width at half maximum of beam profile at depth of 7 cm of water is conventionally taken as beam size. Another important parameter is pneumbra corresponding to 80%-20% fall off region. The importance is due to dose gradiant needed in SRS to optimize sparing normal tissue. Table 1 shows measured characteristics of collimated radiation field for various collimators.

### *Dose verification and Leakage radiation tests*

A layered plexiglass phantom of head has been designed and constructed. It accomodates two main layers for dose verification and localization accuracy tests. One hundered fifty holes, 1 mm long and 2 mm in diameter, were machined in dose verification layer to accommodate calibrated TL cubes ($1\times1\times1$ mm$^3$). The positions of the holes at the periphery of concentric cycles were chosen in such a way that a 3 mm resolution could be achieved. Simulated stereotactic radiosurgery treatment on plexiglass phantom (figure 7) showed 2 mm isocenter deviation and 3-7% difference between the prescribed and measured dose. By placing LiF chips on estimated positions of eyes and thyroid of phantom received dose were measured.

**Table 1.** Radiation fields characteristics provided by developed collimators.

| Collimator size | 12.5 mm | 15 mm | 17.5 mm | 20 mm | 22.5 mm | 25 mm |
|---|---|---|---|---|---|---|
| ***Penumbra (mm)*** | 3.40 | 3.60 | 3.64 | 3.65 | 3.70 | 3.82 |
| ***FWHM*** | 11.5 | 14.4 | 16.4 | 19.2 | 21.3 | 23.8 |
| ***D100/D200*** | 1.74 | 1.73 | 1.73 | 1.74 | 1.75 | 1.75 |
| ***Dmax (mm)*** | 15 | 20 | 17 | 20 | 20 | 22 |

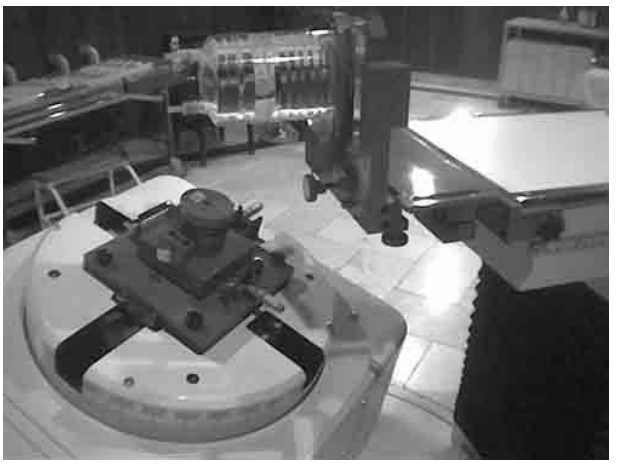


**Figure 7.** Stereotactic irradiation of plexiglass phantom performed in dose delivery accuracy.

For a planned 15 Gy dose to target, eyes and thyroid have received 15 cGy and 8 cGy, respectively. ERGO treatment planning software (3D Line, Italy) was used for target localization, calculation of dose distribution and monitor units.



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## RESULTS AND DISCUSSION

Isocentric alignment test indicated that centers of radiation field and image of steel ball were not exactly coincided (figure 6), corresponding deviations due to gantry and couch motions were 1.5 and 2 mm which were not within established limits (AAPM 1995). By superimposing mechanical isocenter to radiation isocenter for gantry shift and displacing linac's couch for couch shift it was possible to eliminate the effect of isocenteric misalignment (Ramaseshan *et al.* 2003).

For three simulated treatments measured and planned dose difference were 3% to 7% which was within acceptable range(AAPM 1995).

Dose fall off regions (80%-20%) were obtained between 3.4 mm to 3.8 mm for constructed collimators (table 1) which could be acceptable for a linear accelerator possessing 2 mm source size (Chiergo *et al.* 1993). FWHM values have increased in size with increasing collimator size in linear mode (figure 4), showing accurate design and construction of central steel rod to make internal diverging canals. One percent leakage radiation to critical organs such as eyes and thyroid could be taken as an indication of satisfactory safety condition of constructed collimator assembly (Singh *et al.* 1999).

## CONCLUSION

In our institution we have been able to design and construct collimator assembly plus other instruments needed for SRS technique. SRS is a very delicate and precise radiation treatment modality since radiation field is very small and radiation dose very large. Our measured values for critical quantities have been examined against all established standards. It is concluded that SRS collimation assembly described in this article in conjunction with the rest of constructed equipments can be employed to set up SRS treatment, provided safety and compensating operations are taken into account.

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