Physical Aspect of The Gamma Knife and Its Clinical Application

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The first Leksell Gamma Knife unit (LGU-type B) for radiosurgery in Asia was installed in Asan Medical Center. Mechanical accuracy, output, dose profiles for each collimators were measure during acceptance test. Sixty eight patients (sixty nine cases) had undergone radiosugery from May 1990 to September 1990.

AVM cases were 24 cases (35%), acoustic tumor 10 (14%), pituitary adenoma 4 (6%), metastatic tumor 18 (26%), meningioma 6(9%) and others 18 (26%). Dose of 25 Gy-100 Gy was delivered at one time according to disease, location and sizes.

Key Words: Gamma Knife, Radiosurgery

INTRODUCTION

Radiosurgery is a procedure aiming radiotherapy at small intracranial targets, normally 5~30 mm in diameter[1], by multi-directional sharp edged beams of ionizing radiation which crossfire the volume of target. Radiosurgery can be done with multiple directional narrow beams on heavy charged particle[2,3] or high energy photons directed towards the target[4,5].

The great advantage of heavy charged particle is that beams can be designed using 3-idmensional planning program, exactly around target volumes of arbitrary shape. But it has disadvantage of using complicated and expensive accelerator. Gamma knife is a kind of the machine which uses high energy photon (gamma ray). In 1968, Leksell installed his first Gamma knife using ^{60}Co sources at the Karolinska hospital[6]. In the 1980s modified units (with 201 ^{60}Co sources, type A) were installed at number of institutions. The sixteeth unit (type B) was installed at Asan Medical Center in 1990. Unlike type A machine, the distribution of sources is hemispherical. So it has different physical features and different dosimetric characteristics.

Sixty eight patient (sixty nine cases) had undergone gammaknife radiosurgery at AMC from May 1990 to September 1990. In this paper, we describe alignment and the dose distribution of the unit. We also describe the clinical aspect of the radiation surgery for 68 patients.

MATERIALS and METHOD

1. The Structure of Gamma Knife

Gamma Knife consists in radiation unit with 201 ^{60}Co sources, operating table with 4 collimator helmets (4, 8, 12 and 18 mm), control pannel and electrical system, stereotactic instruments and dose planning system.

Unlike type A machine, the ^{60}Co sources are arranged in a sector of a hemispherical surface with a radius 400 mm in type B. (Fig. 1) They are distributed along five parallel circles separated from each other by an angle of 7.5°. The sources are about 60 mm apart. This arrangement gives a longitudinal irradiation angle of about 30°. The hemispherical central body and the poles of the helmet are situated on the centerline of the horizontal axis of the patient. Each beam channel consists of a stationary collimator system located in the central body and an interchangeable final collimator located in the helmet(Fig. 2). The material of interchangeable final collimator is 96% tungsten alloy of 60 mm thickness. This collimator can be replaced by a 60 mm thick plug of same material for beam shielding or beam shaping.

2. Process of Gamma Knife Treatment

For treatment, stereotactic frame (Leksell frame) is fixed to the patient's skull by the four aluminum screw or the four fiber glass rods

The plastic bubble is attached to the frame to define the shape of the skull. (Fig. 3) by measuring

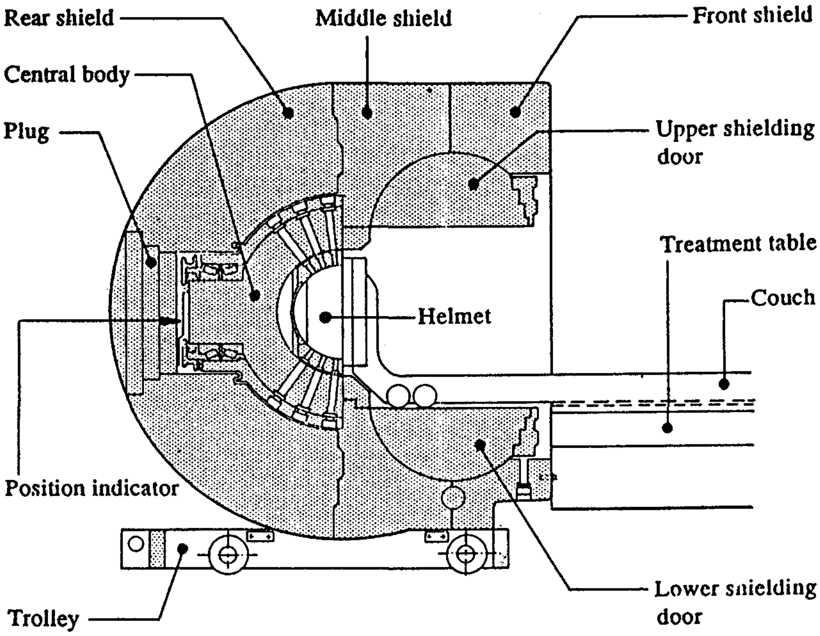

Fig. 1. Schematic diagram of radiation unit of the LGU-type B.

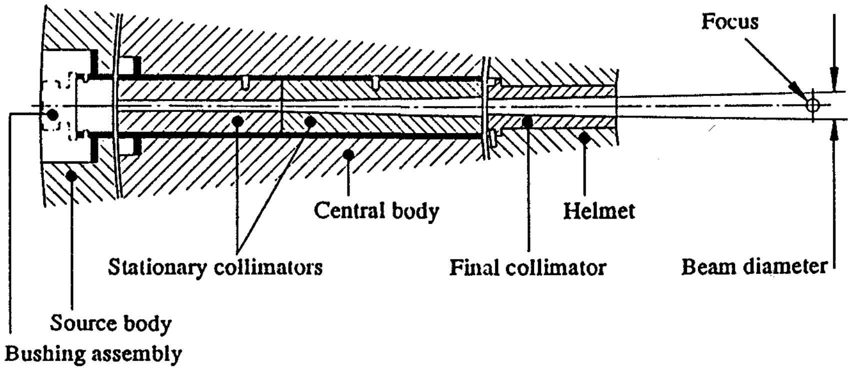

Fig. 2. Cross section of the beam collimating system with helmet.

the distance from the stereotactic frame center to the skull in a number of given direction with the measure stick inserted in each hole in the plastic bubble. Then the X-ray indicator or CT indicator (or MRI) is attached to the stereotactic frame in order to produce radiographs to relate the center and the shape of the target to the coordinate scales. The localization is to identify the target volume and relates its center to a cartesian coordinate system of the stereotactic frame. There are three axes (X, Y and Z axis) in sterotactic frame; Transverse X axis (left to right direction), Y axis from posterior to anterior, and Z axis from cranial to caudal So, this is right-hand-rectangular coordinate system.

Computer planning is performed after localization of target. Micro-Vax II computer* and KULA** computer program are used for planning. During this planning, the standard dose matrix is modified to take into account the shape of the head and the off-center location of the target. One or more shots are used for isodose shaping. Plugs are used in

*Digital Equipment corporation

**Developed in Collaboration between the neurological clinic at Karolinska Hospital and Uppsala University data center

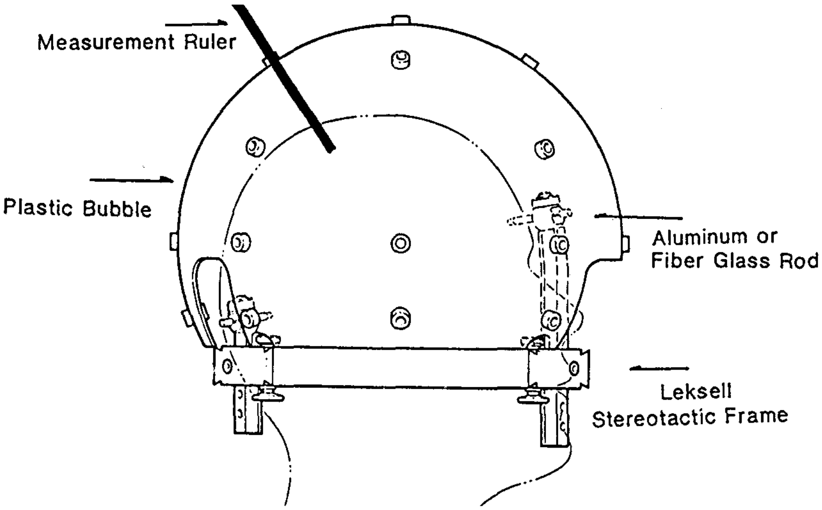

Fig. 3. Plastic bubble. The instrument of measuring the shape of the skull.

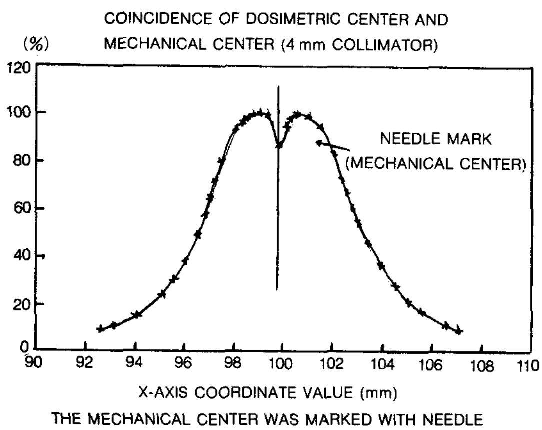

Fig. 4. Perfect alignment between mechanical center and beam center. The arrow in X axis shows less than 0.2 mm deviation (Redrawn from acceptance test report of asan medical center).

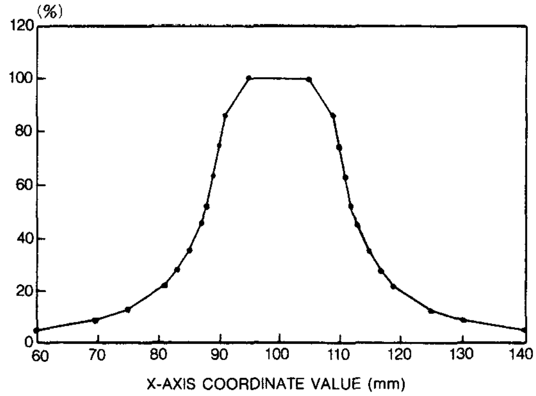

Fig. 5. Dose profile of X axis for 18 mm collimator (Redrawn from acceptance test report of asan medical center).

order to avoid exposure to critical organs such as optic nerve, optic chiasm, and brain stem etc. Leksell Gamma Unit supports are attached to both sides of the frame after dose planning. Y scale (in both sides of the frame) and Z scale (in support side) are adjusted. X axis is set within helmet itself, X scale is on the trunnion attached in the helmet.

3. Dosimetry

The check list and tolerances of the mechanical accuracy are listed in table 1. The beam center and unit center (mechanical center) is measured with the film and the tool which contains a sharp needle, the tip of which is located on the common axes of the trunnions. A small pieces of film can be placed in the tool.

The needle tip can be accurately aligned at the mechanical defined unit center point. The distance between the needle mark and center point of the full width at half maximum (FWHM) of the density profile. The dose rate (or output) is measured with a small thimble chambers at the center of a spherical polystyrene phantom 160 mm in diameter. The phantom was irradiated by beams defined by the 18

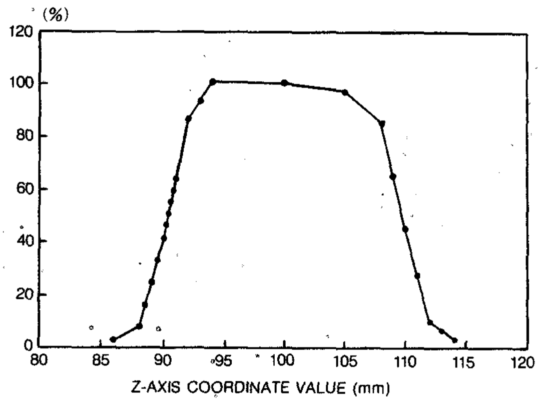

Fig. 6. Dose profile of Z axis for 18 mm collimator (Redrawn from acceptance test report of asan medical center).

mm collimator helmet. The 0.125 cc chamber (PTW 233642) and the 0.07 cc chamber (Capintec PRO5P) are used. The former chamber was calibrated at SSDL (secondary standard dosimetry lab) in Sweden and the latter at SSDL in Seoul. Two output results from each chamber was compared. "Radiation Standard Dosimetric Protocol"[7] was used for the evaluation of absorbed dose. Time end effect was measured using graphic method. Graphic film (Agfa Gaevart Litex N515P) was used for dose profile. The film was calibrated with broad ^{60}Co beam. Densitometer (Mcbeth TD 904) was used when film reading, with 0.05 mm spacing.

4. Clinical Application

Sixty eight patients (sixty nine cases) had undergone from May 1990 to September 1990. AVM

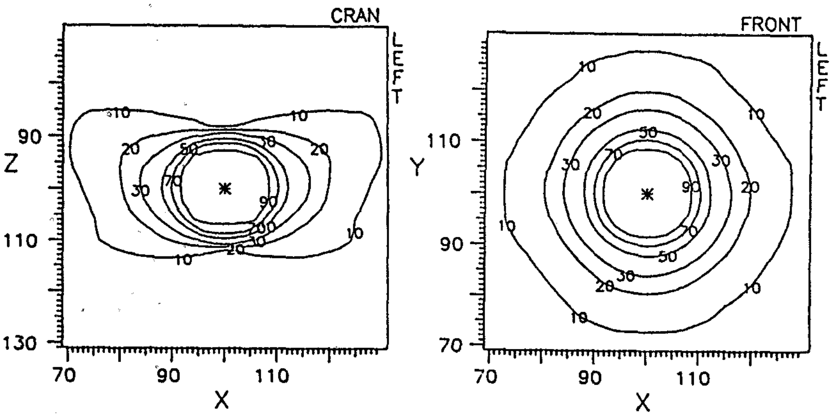

Fig. 7. Isodose distribution for 18 mm collimator.

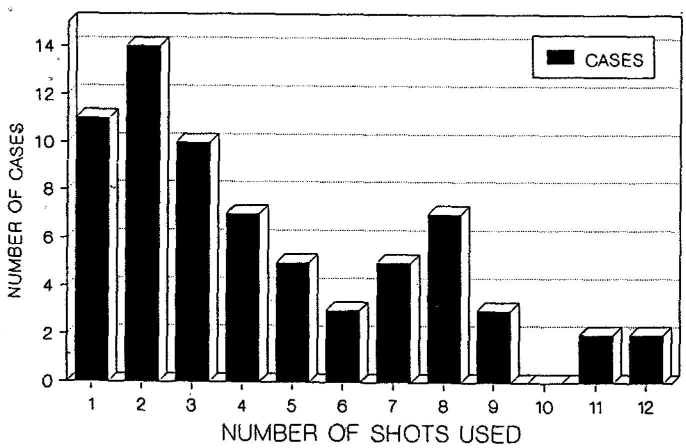

Fig. 8. Number of shots used during dose planning. number of shots depends on target size and shape of target.

cases were 24 casses (35%), acoustic tumor 10 (14%), pituitary adenoma (6%), metastatic tumor 18 (26%), meningioma 6 (9%) and others 18 (26%). (Table 2)

Number of shots collimator sizes and beam weights were selected according to the shape or the size of the target or the of the target.

RESULTS AND DISCUSSION

The results of all the measurement in table 1 were within specification. Deviation between the mechanical center and dose center was less than 0. 2 mm (FIG. 4) Dose profiles of X and Z axes are shown in Fig. 5 and Fig. 6. The profile from film reading shows good agreement with that generated from computer. Dose profiles of X and Y axes were completely identical because X and Y axes are symmetric from the structure of the helmet. Dose profile of Z axis (Fig. 6) shows asymmetric characteristics because of the distribution of source. Absorbed dose of cranial direction is higher than caudal direction in plateau region of dose profile. Fig. 7 shows dose distributions of X and Z axes from planning software KULA. Dose rate was 3.917 Gy/min for 18 mm collimator on May 1990 and the deviation of the results from two different chamber (calibrated separately) was less than 1%. Time end effect of the 18 mm collimator was 0.5 second (3 cGy). Average target volume for all the cases was 7.5 cm^3 (2.4 cm diameter sphere equivalent) and average 4.4 shots used per patient. (Fig. 8) The major complications of radiosurgery were not observed.

But two patient complained of dizziness and nausea after treatment. Three patients developed seizure and two patients whose target were superficial show partial alopecia. Two patients of the AVM cases had taken follow-up MRI scanning after seven months of radiosurgery. Tumor was decreased in one patient and no change was detectable in the other. Steiner et al. report angiographic obliteration of intracranial AVM in 37% of the patients after 1 year or treatment, in 81% after 2 years and in 97% 3 years after treatment.

Table 1. Check List and Tolerance of the Mechanical Accuracy

List	Accuracy
Trunions for Head Fixation	+0.1mm
Stereotactic Frame System	+0.1mm
Correct Treatment Position (between Helmet and Central body)	+0.1mm
Mechanical Center and Beam Center Alignment	+0.5mm

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Table 2. Cases Treated with AMC Gamma Knife between May. 1990 and Sep. 1990

Lesion No. of Pt.	A.V.M.	Acoustic	Pituitary	Meningioma	Pinealoma	Metastatic	Others	Seizure
Non-Op	19	1	3	5	1	6	7	4
Op	5	9	1	1		1	6	
Total	24	10	4	6	1	7	13	4

Total ; 69

= 국문초록 =

감마나이프의 물리적 특성 및 그의 임상적 적용

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이병용 · 장혜숙 · 최은경 · 황충진* · 권 양*

정위 방사선 수술 전용의 감마나이프 (LGU-type B)가 아시아에서 처음으로 본원에 설치되었다. 인수 시험을 위하여 기계적 정밀도, 선량률, 각 콜리메이터 크기에 따른 선량 분포등의 특성을 조사하였다. 1990년 5월 7일부터 1990년 9월 10일까지 총 68명 69예의 환자에게 방사선수술을 시행하였다. 환자별로는 AVM 25예(35%), Acoustic tumor가 10예(14%), Pituitary adenoma가 4예(6%) metastaic tumor가 7예(10%) meningioma가 6예(9%) 기타가 18예(26%)등이었다. 질병 및 병소, 크기에 따라 25 Gy~100 Gy를 1회에 조사하였다.