Dose Attenuation in the Mid-Cranial Fossa with 6 MV Photon Beam Irradiations

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In X-ray irradiation, dose distribution depends on multiple parameters, one of them being tissue inhomogeneity to change the dose significantly. considerable dose attenuation through the mid-cranial fossa is expected because of various bony structures in it.

Dose distribution around the mid-cranial fossa, following irradiation with 6 MV photon beam, was measured with LiF TLD micro-rod, and compared with the expected dose inthe same sites.

In our calculation with C_f (correction factor), the expected dose attenuation revealed about 3. 74% per 1 cm thickness of bone tissue. And the differences between the expected dose with correction for bone tissue and the measured dose by TLD was small, agreeing within an average variation of ±0.21%.

Key Words: Bone correction factor, TLD, Mid-cranial fossa

INTRODUCTION

For several decades radiation therapy had played an essential role in the treatment of pituitary tumors, and efficacy of radiotherapy as the sole treatment modality had been well established[1~4,12].

In addition, it has been shown to be an important adjunct to surgery in reducing the frequency of tumor recurrence[5~7,13].

Hence mid-cranial fossa was composed with various thickness of bone, we could suppose that the tissue inhomogeneity by bone would be produce dose attenuation in photon beam irradiation. However, there have been few reports on the bony attenuation through experimental measurement in the mid-cranial fossa.

So, we carried out dose evaluation within the mid-cranial fossa and reporting the results of it. In this experiment, the results of does attenuation by bone tissue were evaluated with 6 MV linear accelerator, cadaver skull and thermoluminescent dosimeter.

METHODS AND MATERIALS

In the determination of dose distribution at the mid-cranial fossa, adult cadaver skull was used to make the similar condition of patients treatment states. External surface of the skull was coated with paraffins, which have radiologically similar density of the skin tissue and inner portion of the skull was filled with water, which have similar density of the brain. Also base of the skull was mounted on the styrofoam in order to reproduce the correct position as shown in (Fig. 1A).

LiF TLD (thermoluminescent dosimetry) was used for dosimetry and TLD-fixer was used for fixation of TLD on each measurement points during every experiments. Anatomical value of the each measurement points (Fig. 2B) and schematic diagram of the TLD fixer is shown (Fig. 2A). Each TLD was loaded on the fixer and they were settled on the skull (Fig. 1B).

The irradiated TLD would be showing the typical glow curve when temperature raise, and each TL-intensity is proportional to the radiation absorbed doses. However, each TL element even though the same batches has some different responses on sensitivity[14,17]. Therefore, prior to our experiment, we tried to normalized them to the dose of 100 cGy for 6 MV X-rays and evaluated by the TL reader (Victoreen Model 2800) with standard heating cycle. In our study, this procedure was repeated for 9 times and their results is represented (Fig. 3). Residual dose of the irradiated TLD was annihilated for 3 hours at 300℃ and 16 hours at 80℃.

Computed axial tomogram was done parallel with the irradiation beam axis and scanned with slice thickness of 4 mm and scan interval of 2 mm over the irradiation field (Fig. 5). The bone thickness was determined by summation of the whole bone structure between the external surface of the skull and the each measurement points from the C. T. scan.

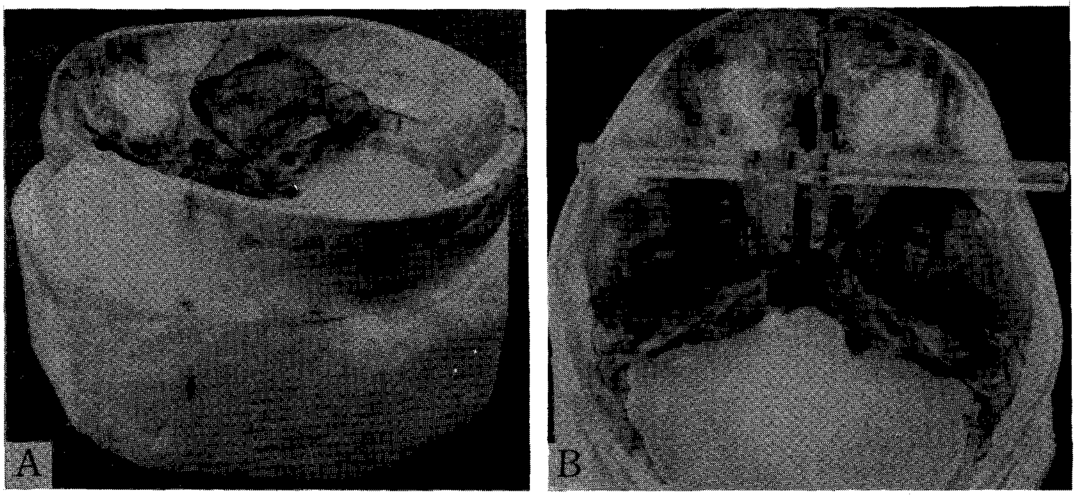
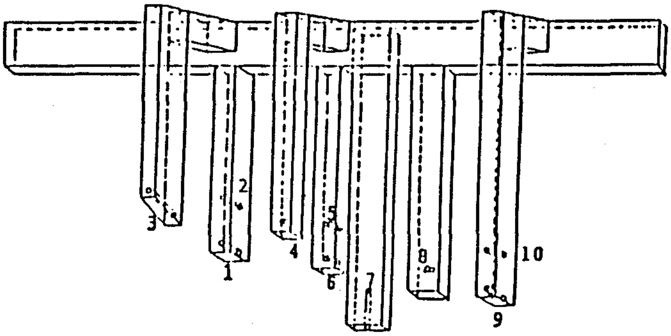


Fig. 1. A ; The cadaver skull was mounted on the styrofoam for fixation during irradiations, and the surface of the skull was coated with paraffin for compensating the soft tissue.
B ; Plastic TLD fixer was inserted in the cadaver skull. TLDs were loaded at each tip of the fixer.

A



B

Position	Anatomical value
1	Below the pituitary gland
2	Center of the pituitary gland
3	Optic chiasm
4	Optic nerve
5	Side of the pituitary gland
6	Cavernous sinus
7	Groove for internal carotid artery
8	Lower portion of the temporal lobe
9	Lower portion of the temporal lobe
10	Lower portion of the temporal lobe

Fig. 2. A ; Schematic diagram of the plastic TLD fixer.
B ; Anatomical value of the each site of measurement.

Expected dose attenuation by bone absorption was calculated by using the correction factor (C_f) which is presented as follows[15].

$$C_f = e^{\bar{\mu}(d-de)}$$

$\bar{\mu}$: effective linear attenuation coefficient

d : depth (cm)

de : soft tissue equivalent depth (cm)

where (d) represents for the depth of measurement points, (de) for soft tissue equivalent depth for the bone thickness and ($\bar{\mu}$) for effective linear attenua-

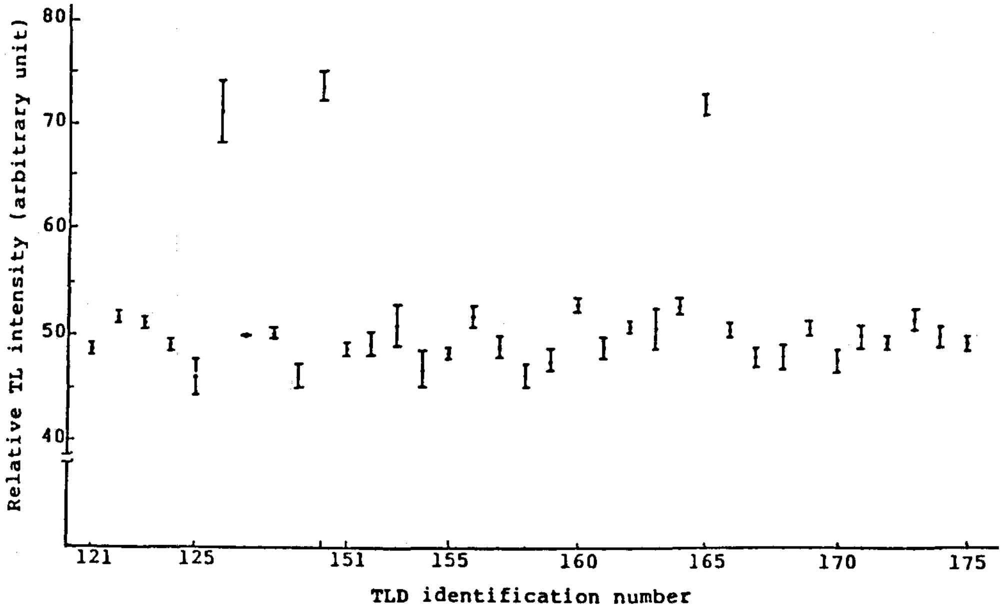


Fig. 3. Relative TL intensity and reproducibilities. The intensity of each TLD was normalized to dose of 100 cGy for standardization.

tion coefficient of 6 MV X-rays. expecially, effective linear attenuation coefficient was derived from the ratio of TMR_{25} to TMR_{10}[15]. In this experiment, ($\bar{\mu}$) was 0.0484±0.0004 cm^{-1} for 6 MV X-ray of MEVATRON KD 8067 dual energy linear accelerator.

The cadaver skull was irradiated with right lateral portal and 5 cm×5 cm was used as irradiation field in SAD (source-axis distance) technique. 100 cGy was irradiated at the lower portion of pituitary gland (position 1) without correction for bony attenuation.

RESULTS

The reliabilities of LIF TLD micro-rod (1 mm×6 mm) sensitivity had been studied by 9 times repetition of experiment is shown (Fig. 3), maximum error ±4.2% and all of them was within average error of ±1.88%.

From the computed tomogram by 2 mm scan interval, the depth is obtained and listed on Table 1. 7.0 cm from the external surface of the skull to the lower portion of pituitary gland (position 1) and 10. 0 cm to the lower portion of temporal lobe (position 9 and 10). Also there are listed bone thickness from C.T.. Bone thickness was noted as 0.5 cm from the external surface of skull to the center of pituitary gland (position 3) and 2.5 cm to the groove for internal carotid artery (position 7).

Expected dose (A) represent the uncorrected dose for bone attenuation and it was decreased with depth. Namely, the dose of the lower portion of pituitary gland (position 1) was 100 cGy and the lower portion of temporal lobe (position 9 and 10) was 83.5 cGy.

Expected dose (B) represent the corrected dose with C_f for bone attenuation. Dose attenuation at the maximum bone thickness (position 7; groove for internal carotid artery) was 11.2%.

Expected dose attenuation ratio per 1 cm of the bone tissue was derived from dose attenuation by the bone tissue. Comparing the dose attenuation per 1 cm of bone thickness at the most thick site (position 7) with the most thin site (position 2) was 4.5% and 4.3%, respectively. And average 3.74% dose attenuation per 1 cm of bone thickness was expected.

Expected dose (A), (B) and measured dose (C) by TLD was listed on the Table 2. The measured dose (C) on Table 2 was averaged doses through the 27 times of inadiation at each measurement sites. The results of this experiment was shown on Fig. 4. and the absorbed doses error of maximum, minimum and average was ±3.3.% at position 3 and 6, ±1.1% at position 1 and ±1.98% at all sites, respectively.

Relative error ratio between expected dose (A)

Table 1. Expected dose Attenuation by Bone Tissue

Locations	1	2	3	4	5	6	7	8	9	10
Depth (cm)	7.0	7.0	7.0	8.0	8.0	8.0	8.5	9.0	10.0	10.0
Bone thickness (cm)	0.6	0.5	0.8	0.8	0.6	0.9	2.5	2.1	1.0	1.3
Expected dose : (A)	100.0	100.0	100.0	94.3	94.3	94.3	91.6	88.8	83.5	83.5
(cGy) : (B)	97.9	97.9	97.3	91.7	93.1	91.3	82.4	81.6	80.4	79.4
Attenuation ratio (A–B/B) x 100 (%)	2.2	2.2	2.7	2.8	1.3	3.3	11.2	8.8	3.9	5.2
Attenuation ratio /Bone (%/cm)	3.6	4.3	3.6	3.5	2.2	3.7	4.5	4.2	3.9	4.0

(A) : Expected dose without bony attenuation.
(B) : Expected dose with bony attenuation.
* Average attenuation ratio/1cm of bone thickness = 3.74 %/cm

Table 2. Expected vs. Measured dose with TLD

Locations	1	2	3	4	5	6	7	8	9	10
Expected dose : (A) (cGy)	100.0	100.0	100.0	94.3	94.3	94.3	91.6	88.8	83.5	83.5
Expected dose : (B) (cGy)	97.9	97.9	97.3	91.7	93.1	91.3	84.4	81.6	80.4	79.4
Measured dose : (C) with TLD (cGy)	97.5	96.5	100.0	89.4	89.3	86.0	82.4	83.4	82.5	82.3
Relative error ratio (A–C/C) x 100 (%)	2.6	3.6	0.0	5.5	5.6	9.7	11.1	6.5	1.2	1.5
Relative error ratio (B–C/C) x 100 (%)	0.4	1.4	–2.7	2.5	4.1	5.8	0.0	–2.2	–2.6	–3.6

(A) : Expected dose without bony attenuation.
(B) : Expected dose with bony attenuation.
(C) : Expected dose with TLD.

and measured dose (C) was also listed (Table 2). At the position 7 (groove for internal carotid artery), expected dose 91.6 cGy and measured dose 82.4 cGy was noted, but at the postion 3 (optic chiasm), dose (A) and (C) showed same value despite of 0.8 cm bony thickness.

In the relative error ratio between dose (B) and (C) at the position 7 was exactly same as 82.3 cGy and average of them was +0.21%.

DISCUSSION

Most of the tumor arising from mid-caranial fossa is developed around the sella turcica, and one of them is pituitary tumor accounting for about 10% of all intracranial neoplasms[4,8~10].

These tumors are usually treated by surgery, radiation or a combination of the two. Hormone secreting tumors of small size was easily detected by clinical symptom and their treatement results was good with transsphenoidal resection of tumor[9,11]. But, most of the pituitary tumor grow very slowly and clinical symptom was not developed until mass cause compression or irritation on the adjacent tissues. So many pituitary tumors was treated as maximal resection combination with radiation therapy or radiation therapy alone after cyto-patholgical confirmation[6,7,12].

Dose distribution is depends on the energy of radiation source, the size and shape of irradiation field, the depth in tissue, the distance from radiation source, the beam collimation, the surface irregurality and the tissue inhomogeneity etc [18~21].

LiF TLD (LiF; 25%, Teflon; 75%) used in this experiment showed good reliability with average error of ±1.88%, which was obtained from repeat-

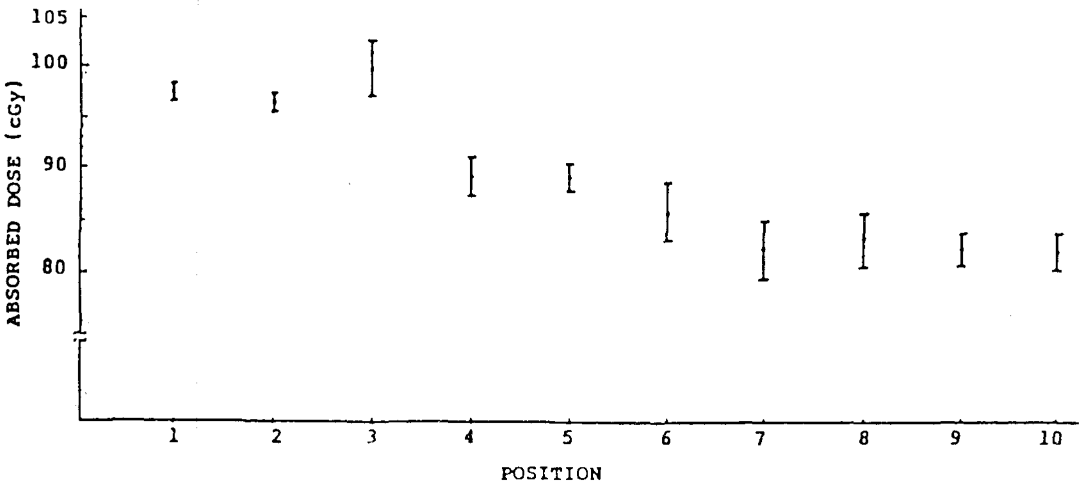


Fig. 4. Absorbed dose (cGy) at the given measurement positions in the cadaver skull.

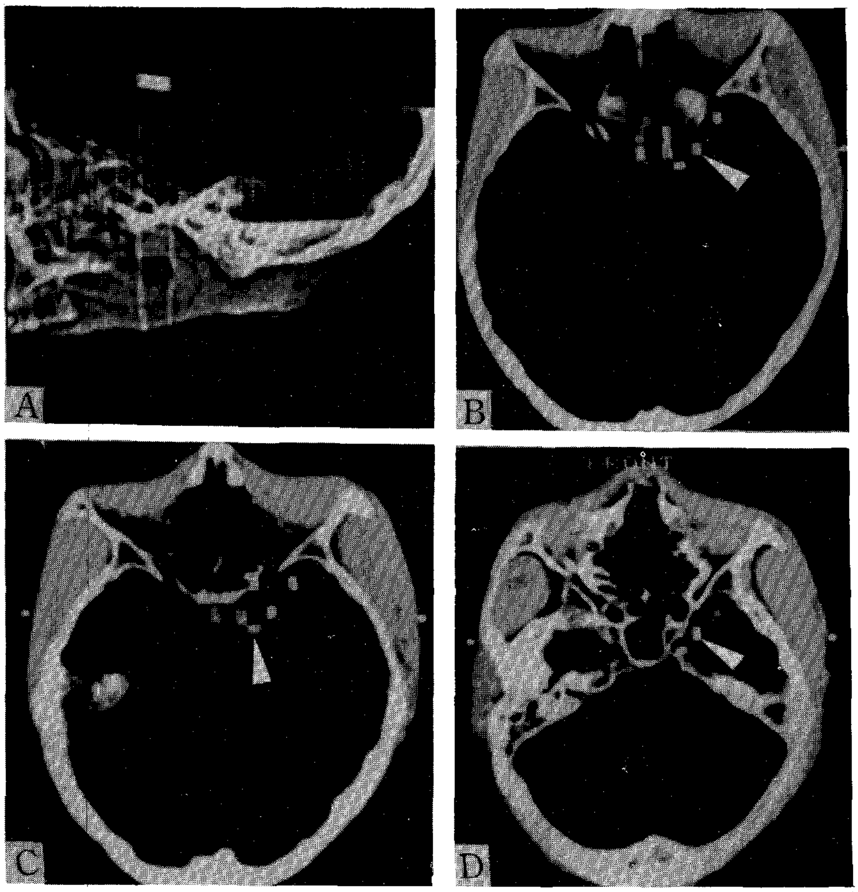


Fig. 5. Images show the computed tomography of the cadaver skull. The topography shows the scan levels with 2 mm intervals. And small white square images (arrow heads) measurement points.

A ; Topography B ; above 1 cm from the center

C ; The center D ; Below 0.6 cm from the center ed exposure of 9 times to each TLD. Also LiF TLD have some advantages such as small in size, little fading of the stored TL signals, and repeated uses. So it is most frequently used for clinical dosimetry[14,18].

The results of experiment after repeated measurement of 27 times on each anatomical point revealed excellent dose reproducibility within average error of +1.98%.

Comparing the expected dose without adjustment of correction factor with the actually measured dose, the maximal dose difference was 11.2% at the groove for internal carotid artery, where the thickness of bone is maximum among the measured points. But despite of presence of bone tissue between skin and optic chiasm, 0.8 cm, there was no difference in two doses. It may be due to the measurement error ±3.3% at that position (Fig. 4) and TLD reliability error average +1.88% (Fig. 3).

The differences between expected dose with adjustment of correction factor and measured dose were small, agreeing within average error of ±0.21%. So we could use this expected values, calculated for dose attenuation by bone tissue with accuracy. Being taken consideration of correction factor for bone tissue in 6 MV photon beam irradiation, we could expect that the average dose attenuation is about 3.74% per 1 cm thickness of bone.

When the photon beam energy is lower than 6 MV, the attenuation by bone would be greater than the values of the Table 1 and 2[15,18,19]. Then it should be adjusted by correction factor for bone to obtain ideal isodose distribution.

Accurate evaluation of dose distribution on mid-cranial fossa would be helpful for us to plan more proper dose on the tumor and lesser dose on the normal tissue in the radiation therapy. With the results of this experiment, we could expect for improving local control rates and diminishing normal tissue damages.

CONCLUSION

In 6 MV photon beam irradiation, expected dose attenuation ratio was average 3.47% per 1 cm thickness of bone tissue, being adjusted by correction factor for bone.

The maximum attenuation sites was the groove for internal carotid artery, where bone thickness was 2.5 cm and the attenuation rate was ±11.2%.

The reliability of TLD used in this experiment was good, showing average error of ±1.88%.

As a result of 27 times repeated TL measurement on each measuring point around the sella turcica, dose reproducibility was acceptable, average error of +1.98%.

The differences between the expected doses with adjustment of correction factor and the measured doses was small, within average error of ±0.21%. So it is advisable to apply the correction factor for bone at the site of tissue inhomogeneity.

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= 국문초록 =

6 MV X-선 조사시 중두개와에서의 선량감쇠

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방사선조사시 선량분포에 영향을 미치는 여러가지 요소들 중에서 조직불균등성은 선량을 상당히 변화시킨다. 특히, 중뇌강은 여러골조직으로 구성되어 있어 조직 불균등성에 따른 상당한 선량감쇠가 예상된다.

6 MV X-선 조사후 중두개와에서의 선량분포측정은 LiF TLD 소자를 이용하였으며 같은 측정장소에서, 계산에 의한 예상선량과 실측선량의 비교를 시도하였다.

계산에 의하면, 골조직 1 cm당 예상선량감쇠는 3.74%를 나타내었다. 한편, 골조직을 고려한 예상선량과 실측선량의 차이는 매우 적었으며 ±0.21%의 오차범위내에서 일치됨을 나타내었다.