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DOSE DISTRIBUTION ANALYZE OF THE BODY STI USED MONTE CARLO METHOD

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Abstract

In Japan, the mortality by lung cancer is increasing. Today, by intensive irradiation technique which dose distribution improved, radiotherapy has come to be considered as an effective treatment method. The Stereotactic irradiation using a linear accelerator has been adopted widely in the many hospital recently. Accurate dosimetry for radiotherapy is important to determine the absorbed dose of target volume.

However, some problems were arisen by Stereotactic irradiation with the small irradiation field. In lung, recoil electron travels a longer distance, therefore it reaches out of an irradiation field. Furthermore, the number of recoil electrons per unit volume is less than in soft tissue. A secondary electronic equilibrium does not exist. As a result, it is difficult to determine the absorbed dose distribution.

In this study, the absorbed dose distribution in a thorax was calculated using the EGS4 Monte Carlo simulation. The variation of the absorbed dose distribution as a function of field size and incident X-ray energy were investigated.

1. Introduction

In Japan, the mortality rate by lung cancer is increasing. In the death caused by a cancer, there is much death of no. 1 by lung cancer at a male, and no. 2 at a female. Previously, the first choice of lung cancer treatment was surgical operation.

In radiotherapy, the most important thing is to irradiate target volume with the optimal dose and to minimize side effects. In conventional methods, there was probability of terrible side effects like pneumonia caused by the irradiation to the periphery of a tumor. By intensive technique to irradiate from every angle, dose distribution has been improved and side effects are decreased. Today, a tumor can be found at an early stage by screening using helical CT, and radiotherapy has come to be considered as a technique of effective treatment.

The Stereotactic irradiation using a linear accelerator has been adopted widely in the many hospital recently. For Stereotactic irradiation, accurate dosimetry is important to determine the absorbed dose of target volume. However, some problems were arisen by Stereotactic irradiation with the small irradiation field. In the case of lung cancer, several tissues constitute a thorax. In lung, recoil electron travels a longer distance, therefore it reaches out of an irradiation field. Furthermore, the number of recoil electrons per unit volume becomes less than a soft tissue. A secondary electronic equilibrium does not exist. As a result, it is difficult to determine the absorbed dose distribution.

In this work, the absorbed dose distribution of a thorax was calculated using the EGS4 Monte

Carlo simulation. The variation of the absorbed dose distribution as a function of field size and incident X-ray energy were investigated.

2. Method and Materials

2.1 VOXEL code

The VOXEL code is an original user code of EGS4[1, 2] which can calculate absorbed dose of 3D-CT like voxel geometry. In this code, source axis distance (SAD), the coordinate of isocenter, the voxel size, the number of voxel and incident spectrum can be set arbitrarily. The field shape can be selected either circular or rectangular field. This code can simulate various irradiation methods, for example, fixed multi-port irradiation, moving field irradiation, pendulum, rotational irradiation, multi-arc irradiation and non-coplanar irradiation.

2.2 Geometrical arrangement

Figure 1 shows the geometrical arrangement of thorax model. A voxel phantom of a simplified lung cancer patient model has been developed based on the MILD-type phantom[3)]. The width of the thorax model was 40 cm and the thickness was 20 cm. This thorax model was composed of 3 regions, chest wall, lungs and lung tumor. The density of the chest wall and the lung tumor were 1.0 g/cm^3, and that of lungs was 0.3 g/cm^3. The sphere shape tumor (2.0 cm diameter) was embedded at center of lung region. This tumor region assumed as gross tumor volume (GTV). And the region with this circumference of 5 mm was set to clinical target volume (CTV).

Generally, three-arc 180-degree pendulum irradiation method (Figure 2) has been adopted to stereotactic irradiation of small lung cancer. Therefore, the dose distribution of this irradiation method was calculated in this work.

2.3 Condition of simulation

The absorbed dose distribution was calculated using EGS4 Monte Carlo simulation. The incident beams were assumed to be point source and fan line beam of photons. The voxel size is 2 mm $\times$ 2 mm $\times$ 2 mm. Field shape was set to a circular field. A set of 1×10^8 photons was generated per batch and 10 batches were performed for field diameter of 3.0, 3.5 and 4.0 cm, respectively. The simulation was performed for 4, 6, 10, 15, 24 MV X-ray beams and photon beam from ^{60}Co-teletherapy unit. Those Spectra data was quoted from Mohan's data[4)] and Saitoh's data[5)].

2.4 Dose distribution analysis

Results data was normalized by dose at isocenter. Relative dose in CTV, GTV and whole of irradiated volume (WHOLE) was drawn as dose volume histogram (DVH). Integral dose and the statistical data (the mean, median, standard deviation (S.D.), maximum and minimum) were computed.

3. Results and Discussion

3.1 Energy dependence

Figure 3 shows DVH of GTV, CTV and WHOLE for a 3 cmφfield as a function of X-ray energy. First of all, we will focus our attention on dose uniformity in GTV. It is an ideal dose distribution that the mean value is closer to 100% and the smaller standard deviation. The statistical data of the dose in GTV of 3cmφ field as a function of X-ray energy was summarized in table 1. In the case of 24 MV and ^{60}Co, the mean value was 90.1 and 100.7, the standard deviation 5.3 and 1.6, respectively. As low energy, the mean value was closer to 100% and the standard deviation was smaller. The result clearly showed that the dose uniformity in GTV has improved with low energy.

The statistical data of the dose in CTV for 3 cmφ field as a function of X-ray energy were summarized in Table 2. In the case of 24 MV and ^{60}Co, the mean value was 75.2 and 96.0, the standard deviation 11.2 and 6.6, respectively. As compared with statistical data in GTV, the mean value was closer to 100% and the standard deviation was smaller with low energy. As a consequence, the dose uniformity of CTV has advanced as low energy.

The dose uniformity in GTV and CTV is influenced of range of the recoil electrons. In soft tissue, difference of the recoil electrons ranges by energy does not turn up largely. However, in the lung, which has low density, the recoil electrons reach more distantly with high energy. As a result, in comparison with soft tissue, dose uniformity of GTV declined. And dose of WHOLE except CTV increased. Therefore, We concluded that the dose uniformity of GTV and CTV was improved with low energy.

3.2 Field size dependence

Figure 4 shows DVH in GTV, CTV and WHOLE of 4 MV as a function of field size. The statistical data of the dose in GTV as a function of field size were summarized in Table 3. In the case of 3.0 cmφ and 4.0 cmφ field, the mean value was 98.2 and 99.5, the standard deviation 2.10 and 1.91, respectively. Even if the field is enlarged, the mean values and standard deviations in GTV showed similar values. Therefore the dose uniformity in GTV was almost equal regardless of field size.

Then, the dose uniformity in CTV was considered. The statistical data of the dose in CTV as a function of field size was summarized in Table 4. In the case of 3.0 cmφand 4.0 cmφ field, the mean value was 89.3 and 97.2, the standard deviation 8.07 and 3.00, respectively. When the field diameter was enlarged from 3 cm to 3.5 cm, the mean value was closer to 100% and the standard deviation decreased from 8.07 to 4.11. When the field was enlarged to 4.0 cm, the mean value became closer to 100%, and the standard deviation becomes a little smaller. That is to say, when a field was enlarged from 3 cm to 3.5 cm, the dose uniformity in CTV was improved. However, when a field was enlarged from 3.5 cm to 4.0 cm, the dose uniformity in CTV was hardly changed. The dose uniformity in CTV was improved by a little expansion of field size. While, the dose uniformity did not change by the expansion of the field size beyond it.

Figure 5 shows the change of the relative integral dose of WHOLE except CTV. The integral dose was normalized with the integral dose of 3.0 cmφfield and ^{60}Co. When a field diameter was enlarged from 3 cm to 3.5 cm, integral dose became 1.4 times approximately. Furthermore integral dose became about 1.3 times for the field diameter 4 cm. It was confirmed that the integral dose increased as a field size. Integral dose of WHOLE except CTV was almost equal regardless of incident energy.

On the radiotherapy, it is important not only to improve the dose uniformity but also to make the integral dose decreased. By enlarging a field size, the improvement of dose uniformity of CTV was found, but it made the integral dose increased.

4. Conclusion

Enlarging a field size is directly related to increasing integral dose. Therefore, neither the integral dose nor the dose uniformity of CTV concurrently can be improved. To optimize irradiate conditions, it is necessary to define score functions, in the future work.

References

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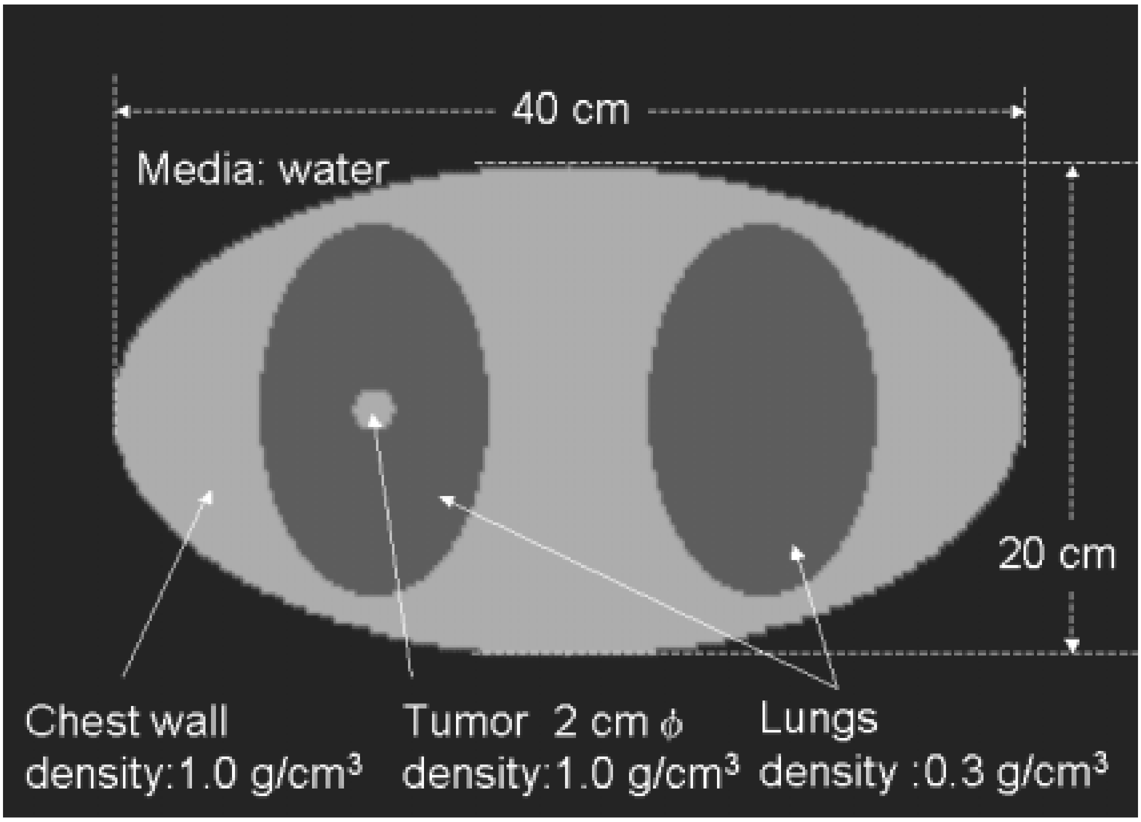


Figure 1 Shape, media and physics properties of thorax model

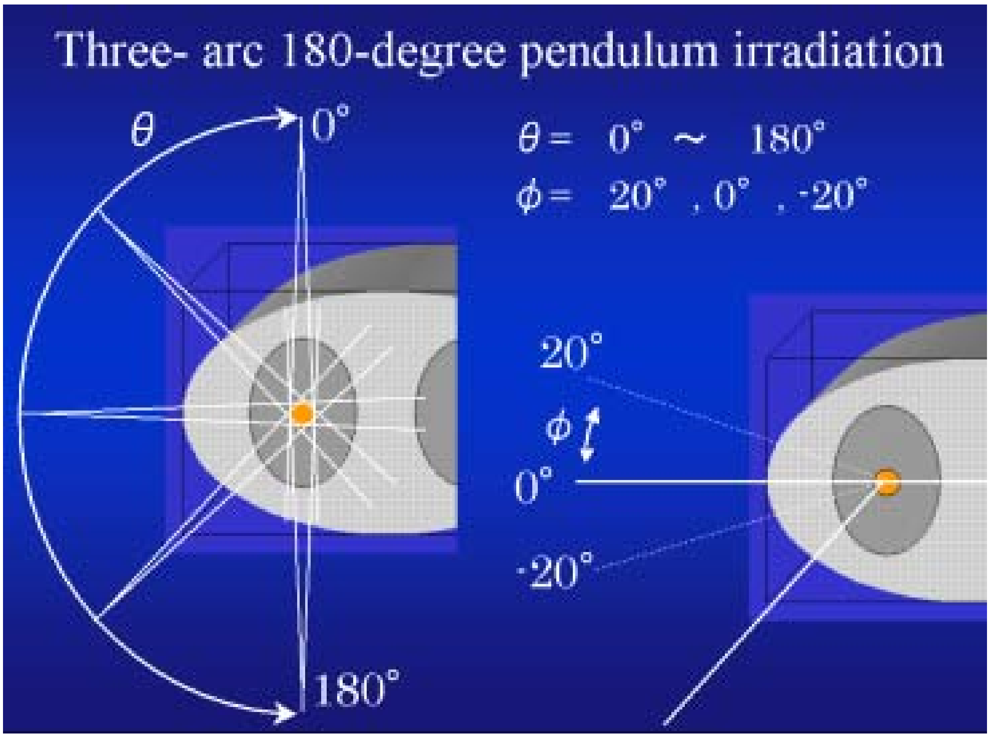
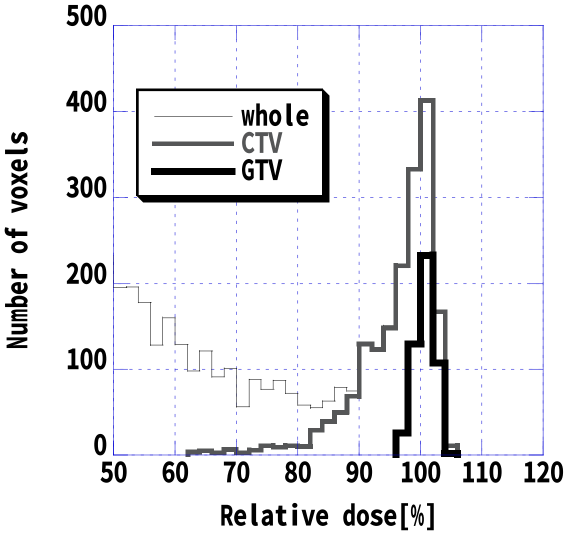


Figure 2 Geometrical conditions for simulation three-arc 180-degree pendulum irradiation.

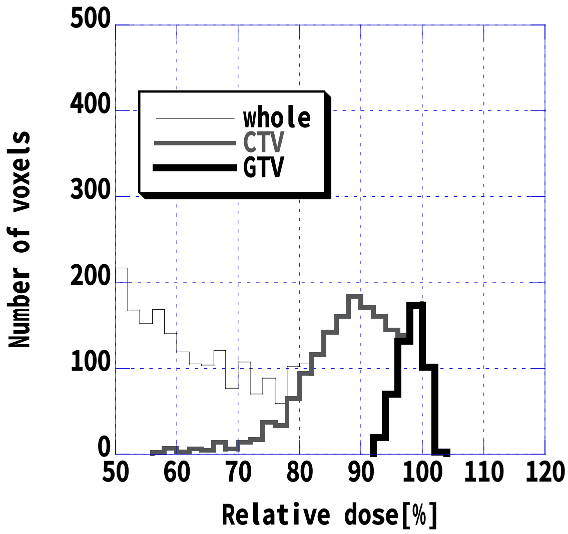
Caption of Fig.3 (e) and (f) is shown here as they can not be shown in the right place.

(e) 15 MV (f) 24 MV

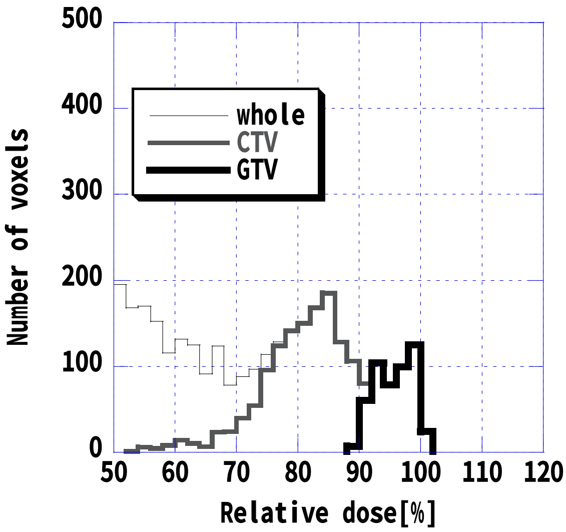
Figure 3 The DVH of GTV, CTV and WHOLE of a 3 cm ϕ field for several energies.



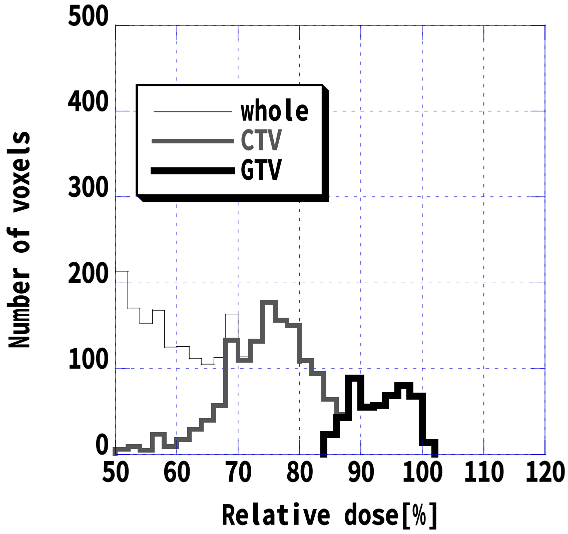
(a) ^{60}Co γ-ray



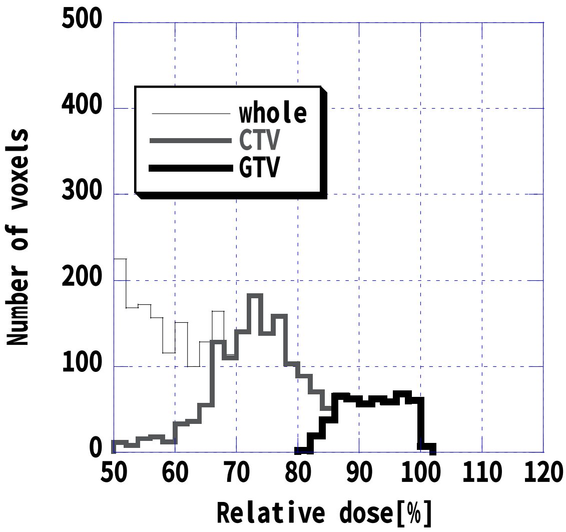
(b) 4 MV

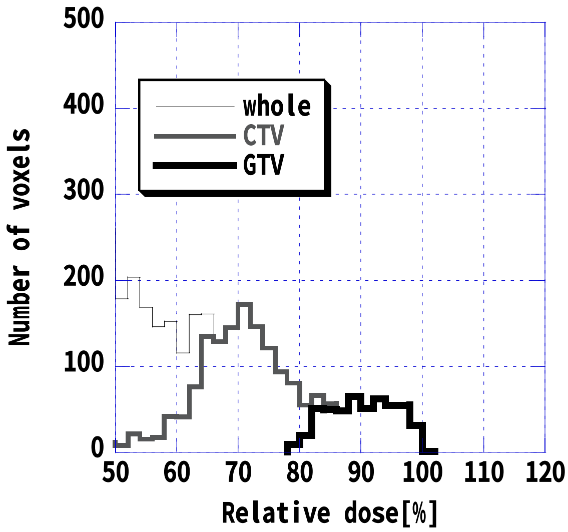


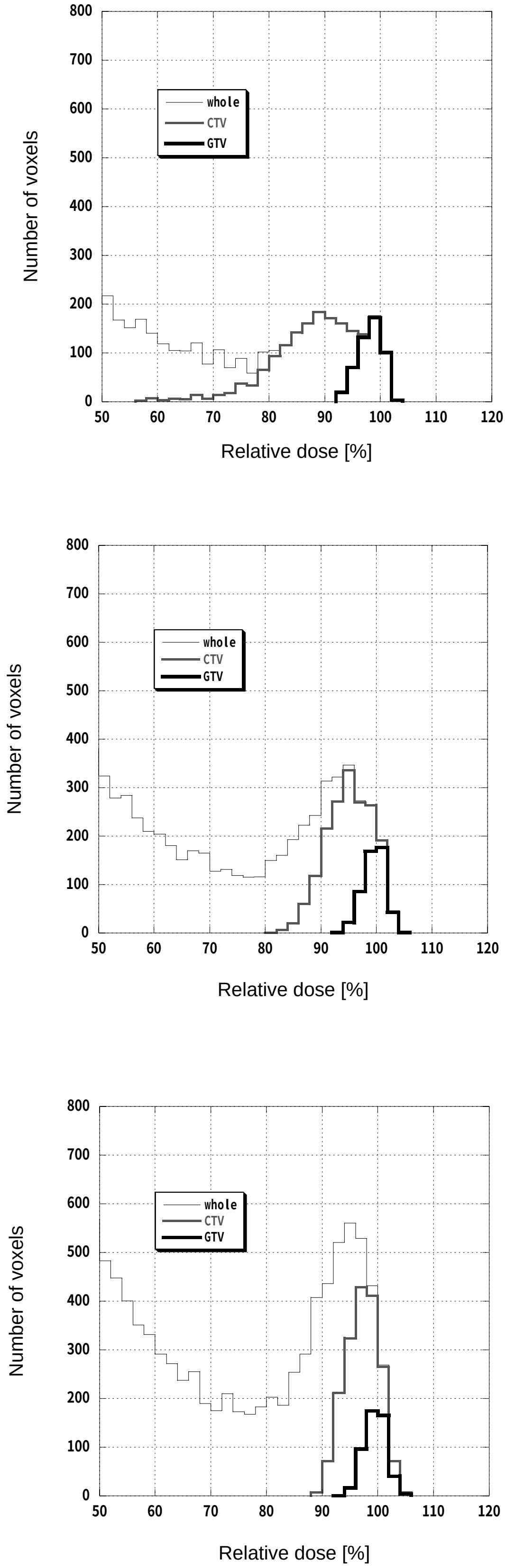
(c) 6 MV



(d) 10 MV







(a) Field size 3.0 cmφ, (b) Field size 3.5 cmφ, (c)Field size 4.0 cmφ

Figure 4 DVH in GTV, CTV and WHOLE for 4 MV of several field sizes

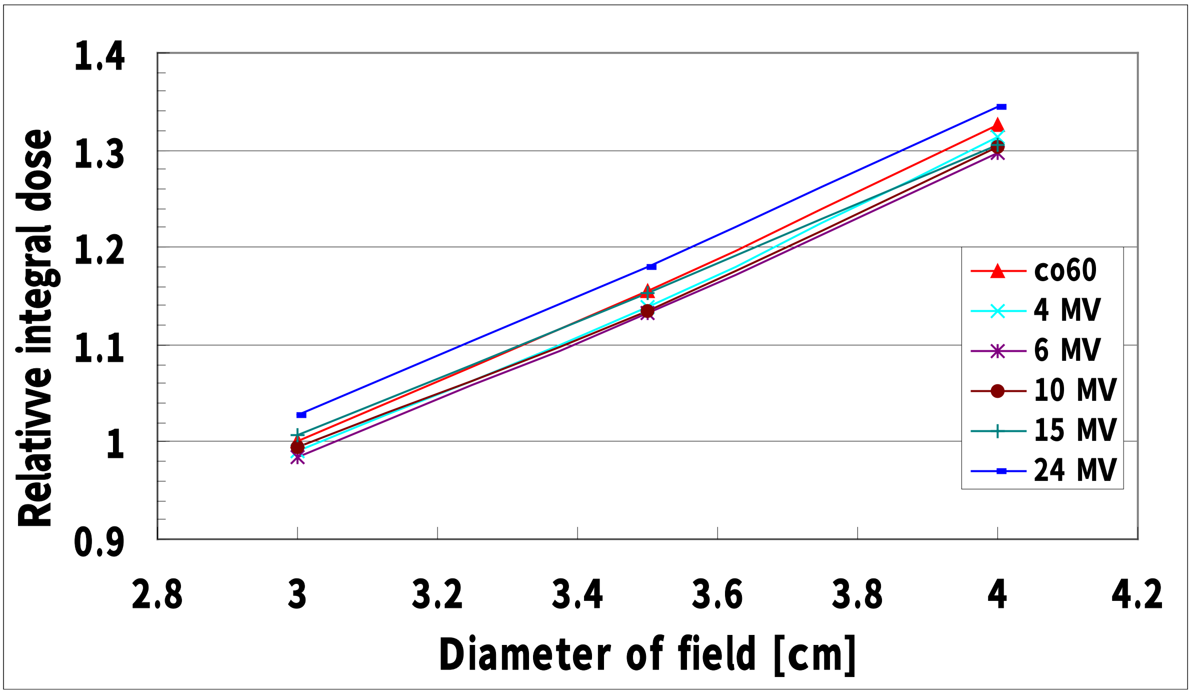


Figure 5 Variation of the relative integral dose of WHOLE except CTV

Table 1 Statistical data of the dose in GTV of 3cmφ field as a function of X-ray energy

	Energy					
	^{60}Co	4 MV	6 MV	10 MV	15 MV	24 MV
Mean	100.7	98.2	95.7	93.2	92.0	90.1
Median	100.9	98.4	96.0	93.6	92.3	90.2
S.D.	1.6	2.1	3.0	4.4	4.8	5.3
Maximum	104.3	102.8	101.3	100.9	100.6	100.6
Minimum	96.4	93.0	88.2	84.1	81.4	79.0

Table 2 Statistical data of the dose in CTV for 3 cmφ field as a function of X-ray energy

	Energy					
	^{60}Co	4 MV	6 MV	10 MV	15 MV	24 MV
Mean	96.0	89.3	84.5	79.4	77.7	75.2
Median	98.1	89.9	84.4	77.9	76.2	73.2
S.D.	6.6	8.1	9.1	10.5	10.8	11.2
Maximum	105.6	102.8	101.3	100.9	100.6	100.6
Minimum	62.2	57.7	53.8	51.0	49.5	48.6

Table 3 Statistical data of the dose in GTV as a function of field size

	Energy 4 MV		
Field size	3.0 cmφ	3.5 cmφ	4.0 cmφ
Mean	98.2	99.5	99.5
Median	98.4	99.7	99.6
S.D.	2.10	1.90	1.91
Maximum	102.8	104.3	105.4
Minimum	93.0	93.0	93.5

Table 4 Statistical data of the dose in CTV as a function of field size

	Energy 4 MV		
Field size	3.0 cmφ	3.5 cmφ	4.0 cmφ
Mean	89.3	95.1	97.2
Median	89.9	95.2	97.4
S.D.	8.07	4.11	3.00
Maximum	102.8	104.3	105.4
Minimum	57.7	81.5	89.4