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A METHOD FOR CALCULATING ABSORBED DOSE IN TISSUE BY Cs-137 NEEDLE USING EGS4

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Abstract

A method using dose rate constant and anisotropy function for calculating absorbed dose distribution in brachytherapy has been recommended by AAPM Report no.51. In 2003, the radiation treatment planning equipment with the method for obtaining the absorbed dose distribution in brachytherapy using Cs-137 needles was introduced into Department of Radiology, Nagoya University Hospital. The method beforehand requires radial dose functions g(r) and anisotropy functions F(r, θ). These functions are decided from known absorbed dose. However, it is difficult technologically to measure the absorbed dose distribution in the vicinity of the Cs-137 needle for brachytherapy. Therefore, we obtained these functions after the absorbed dose distribution had been calculated using a conventional method. The absorbed dose distribution calculated by the conventional method must be compared with the measurement one. In order to verify the accuracy of this method, we compared the absorbed dose distribution obtained with this method and that obtained with EGS4 Monte Carlo simulation. Furthermore, we examined the influence of the geometry of the needle source to the absorbed dose distribution. As a result, both absorbed dose distributions obtained by two methods were good agreement with each other. In addition, there was little influence to the dose distribution on the basis of a difference of the geometry on both ends of the needle.

1. Introduction

AAPM Report no.51[1)] has recommended a method using dose rate constant and anisotropy function for calculating an absorbed dose distribution in brachytherapy. The radiation treatment planning system with the method for calculating the dose distribution using Cs-137 needles has been introduced into Department of Radiology, Nagoya University Hospital in 2003. The method requires radial dose functions g(r) and anisotropy functions F(r,θ). These functions must be decided from known absorbed dose distribution. However, it is difficult to measure the absorbed dose in the vicinity of the Cs-137 needle because the activity of the needle used in brachytherapy is generally very weak. Therefore at first we calculated an absorbed dose distribution by a conventional calculation method in consideration of inside configuration of the needle. We obtained the dose rate constant and the anisotropy function using the dose distribution calculated by the conventional method afterwards. The absorbed dose distribution obtained by this method must be compared with the measurement one. In order to verify the accuracy of this method, we compared the absorbed dose distribution obtained by this method and that calculated with EGS4 Monte Carlo simulation. Furthermore, we examined the influence of the geometry of the needle source to the absorbed dose distribution.

2. Materials and method

1) The method with dose rate constant and anisotropy function for calculating absorbed dose distribution.

In this work, the method with dose rate constant and anisotropy function for calculating absorbed dose distribution has been formulated using radiation treatment planning equipment ECLIPSE (made by VARIAN). Equation (1) shows the calculation method (RTPS) recommended by AAPM, and figure 1 shows the detail of RTPS.

$$\dot{D}(r,\theta) = S_k \Lambda \, g(r) F(r,\theta) \frac{G(r,\theta)}{G(1,\pi/2)} \quad (1)$$

r : Distance from source center to interest point.
θ : Angle with respect the long axis of source.
S_k : Air karma strength
Λ : Dose rate constant
$g(r)$: Radial dose function
$F(r,\theta)$: Anisotropy function
$G(r,\theta)$: Source geometry factor.

where $g(r)$ and $F(r,\theta)$ are defined as Equations (2) and (3), respectively.

$$g(r) = \frac{\dot{D}(r,\theta_0) \; G(r_0,\theta_0)}{\dot{D}(r_0,\theta_0) \; G(r,\theta_0)} \quad (2)$$

$$F(r,\theta) = \frac{\dot{D}(r,\theta) \; G(r,\theta_0)}{\dot{D}(r,\theta_0) \; G(r,\theta)} \quad (3)$$

The reference point was defined at the point (r_0,θ_0), where r_0 =1 cm and $\theta_0 = \pi/2$, respectively. These functions were obtained using the absorbed dose distribution calculated by the conventional method considering source inner structure[1-5].

2) The method for calculating absorbed dose distribution using EGS4.

Figures 2-1 and 2-2 show the source geometry used by EGS4 and the source position in water phantom, respectively. Furthermore, table 1 shows the material data and those details used by EGS4 calculation. Figure 3 shows absorbed dose detection rings (ADDR) and a Cs-137 needle. D_P is the quotient of E_{Total} (the absorbed energy in ADDR) by m (the mass of ADDR). We could shorten the calculation time and decrease the statistical error because absorbed dose at a point had been calculated using ADDR. Total incident particles were about 3.89 x10^8.

3) A comparison method of the absorbed dose distribution.

We compared two absorbed dose distributions normalized with the reference point dose calculated using EGS4 and RTPS. The absorbed dose profile curves at each distance were shown in figure 5. Furthermore, we examined the influence of the geometry of the needle source to the absorbed dose distributions calculated with both methods by turning up those profile curves at the center line.

3. Results

1) Comparison of absorbed dose distributions

Figures 6-1 and 6-2 show the absorbed dose profile curves calculated by both methods. Around center line at the distances of 0.2 and 0.3cm from source, the absorbed dose profile curves calculated with RTPS are slightly lower than those calculated with EGS4. However, other profile curves are good agreement with each other.

2) The influence of source geometry to the absorbed dose distributions.

Figure 7 shows the symmetry of the absorbed dose profile curves calculated with both methods. As a result by EGS4, the doses at needle tip side around center line with the distances of 0.2 and 0.3 cm from source are slightly higher than those at the opposite side. However, the doses at other points show good symmetry and are in agreement with each other. As a result by RTPS, the profile curves show good symmetry at all distances. However, the influence of the geometry of the needle source is not shown.

4. Discussion

Around center line at the distances 0.2 and 0.3 cm from the ^{137}Cs source, the absorbed doses calculated with EGS4 were slightly higher than those calculated with RTPS. The absorbed dose within 1.0cm calculated with RTPS was approximation data because $g(r)$ and $F(r,\theta)$ within 1.0 cm were not inputted into ECLIPSE. However, the difference between both the absorbed dose distributions can be ignored because the difference is very small. Furthermore, the same cause can be considered for the symmetry of absorbed dose profile curve calculated with RTPS as well.

5. Conclusions

In this report, the results calculated by EGS4 and RTPS are in good agreement with each other. The method with the anisotropy and the radial dose function obtained by the conventional method with consideration of source inner structure for calculating absorbed dose distribution is considered useful. The result of the dose distribution is high reliability because both methods are really different.

Acknowledgment

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References

1) L. L. Anderson, G. Luxton, et al.: AAPMs TG-43 Dosimetry of Interstitial Brachytherapy Sources, Med. Phys. **22**(2), 209-234 (1995).
2) JSMP: Standard Dosimetry for Brachytherapy Sources, Tsusho-Sangyo Kenkyu-Sha, Tokyo (2000).
3) W. R. Nelson, H. Hirayama and D. W. O. Rogers: The EGS4 code system. SLAC Report-265 (1985).

Table 1 Material data and details for PEGS4.

		ELEMENT	RHOZ(%)	RHO(g/cm3)	PCUT(MeV)	ECUT(MeV)
source	Caesium			****	0.01	0.521
		Cs	100			
wall	Stenless			7.96	0.01	0.521
		C	0.030			
		Mn	2.000			
		Si	1.000			
		P	0.045			
		S	0.030			
		Ni	14.000			
		Cr	18.000			
		Mo	3.000			
		Fe	61.895			
phantom	Water		**PZ(%)**	1.00	0.01	0.521
		H	66.7			
		O	33.3			

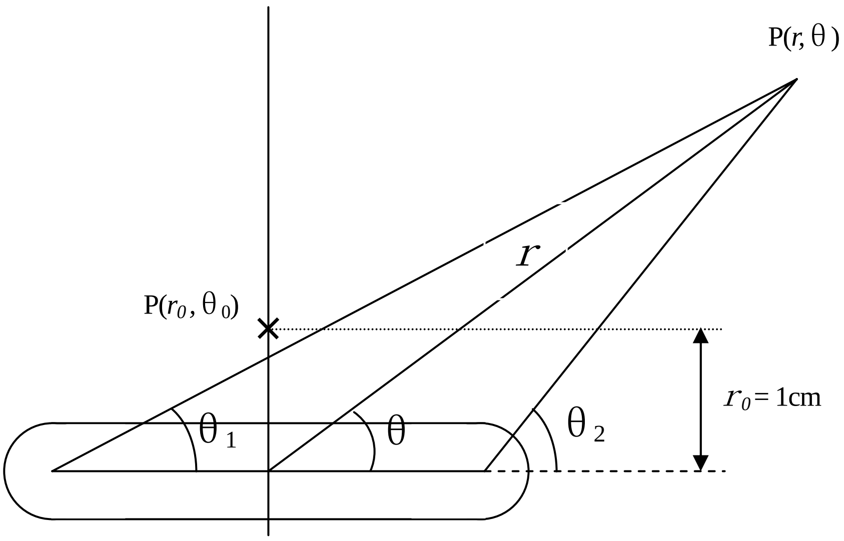


Figure 1 Parameter of the source.

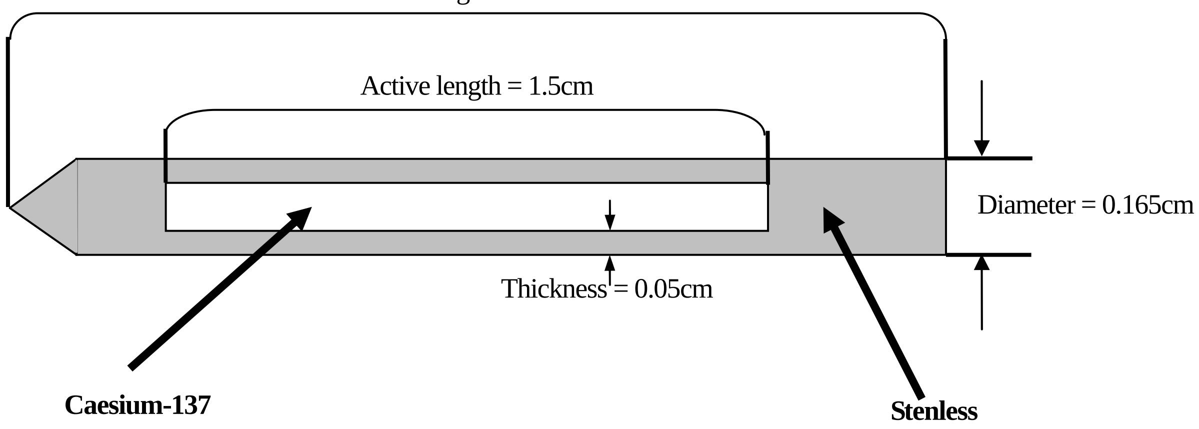


Figure 2-1 Geometry of source.

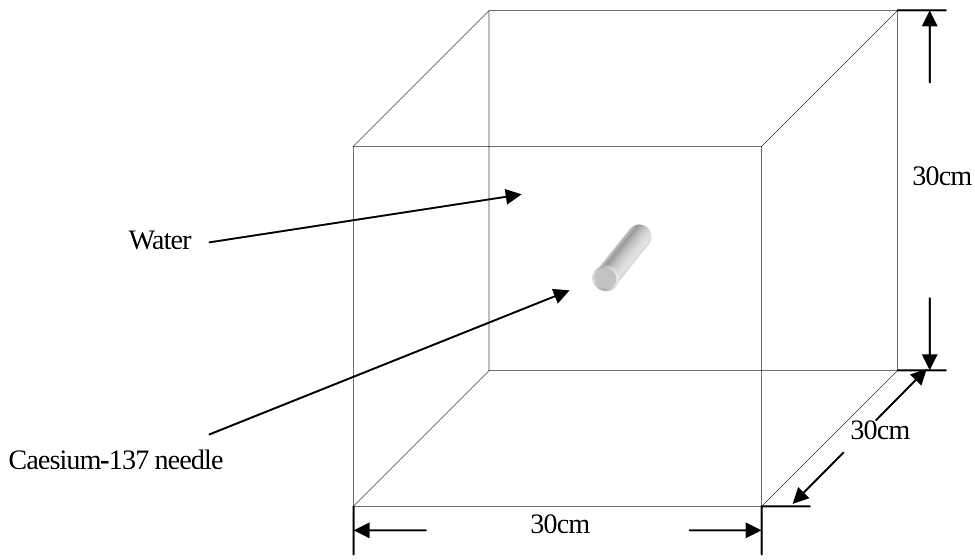


Figure 2-2 Source position in water phantom.

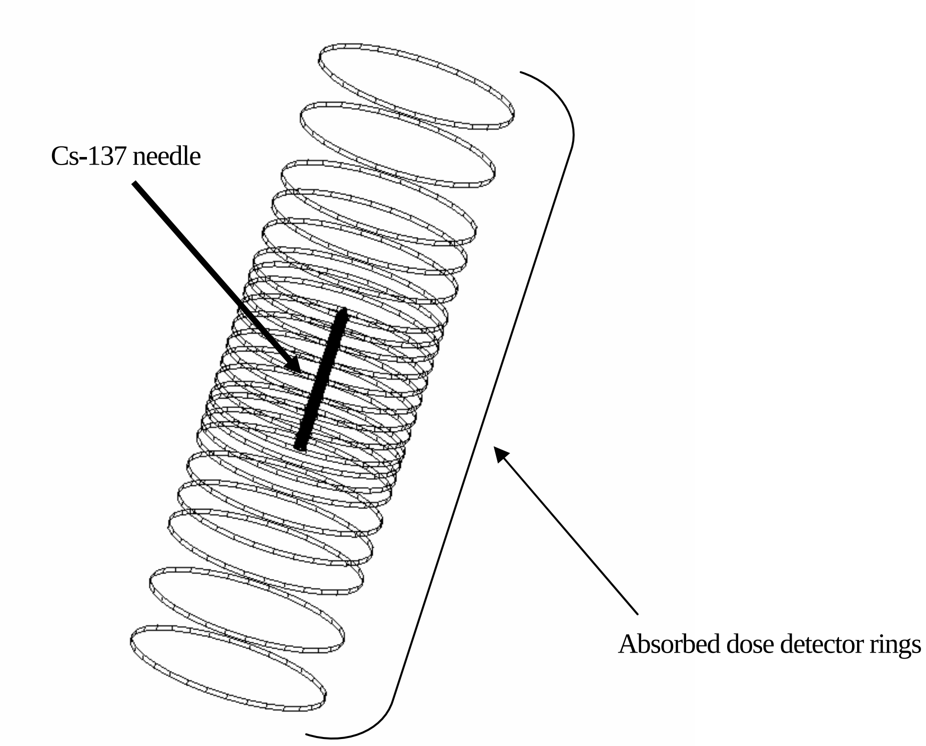
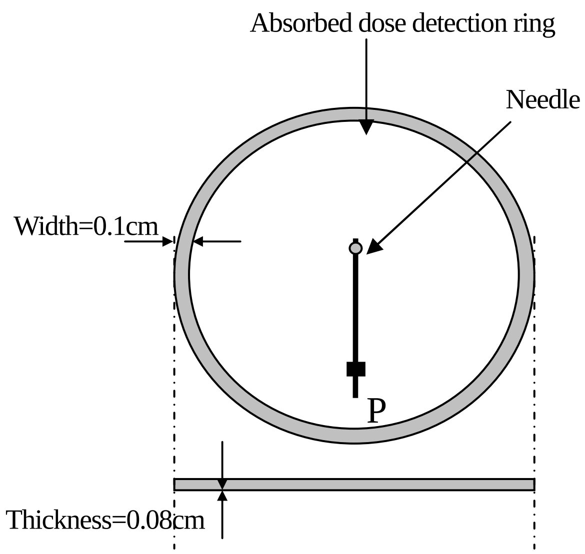


Figure 3　A plane configuration of absorbed dose detection rings.



M : Total mass of ADDR
E_{Totoal} : Total absorbed energy in ADDR
D_P : Absorbed dose at point P

$$D_P = \frac{E_{Total}}{M}$$

Figure 4　The detail of ADDR.

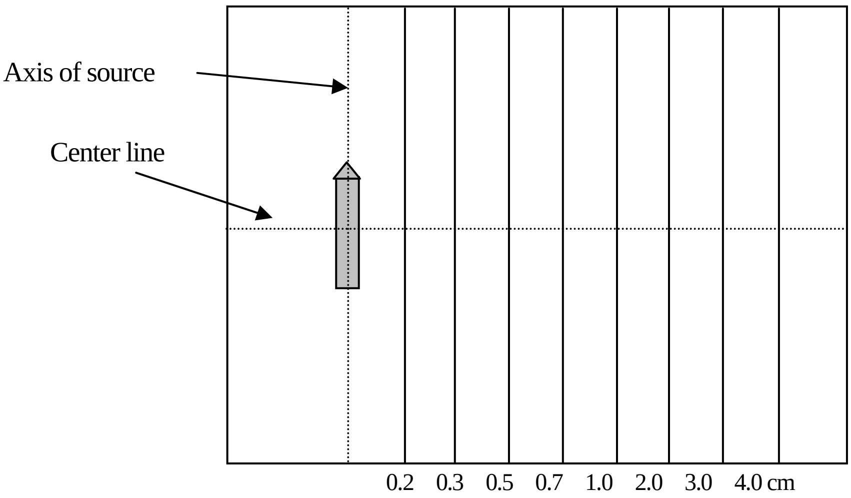


Figure 5 Distances from source for obtaining absorbed dose profile curves.

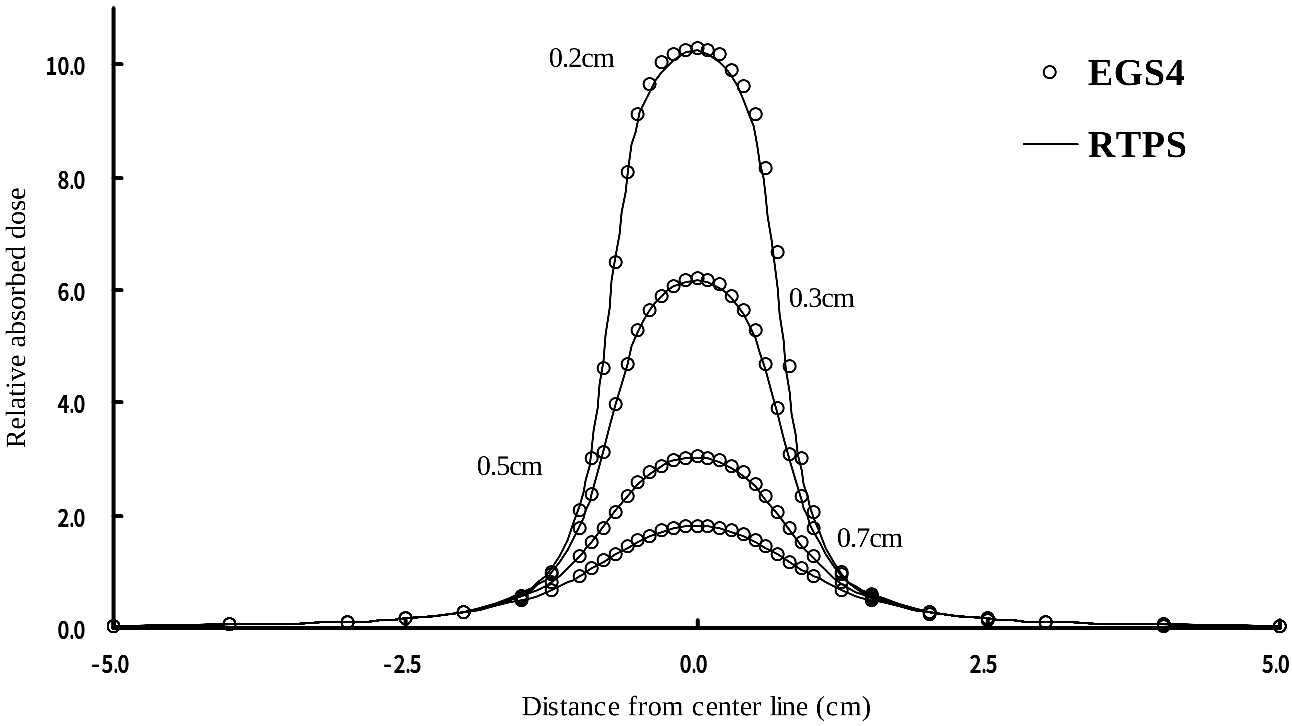


Figure 6-1　Comparison of absorbed dose profile curves obtained by EGS4 and those obtained by RTPS (0.2-0.7cm).

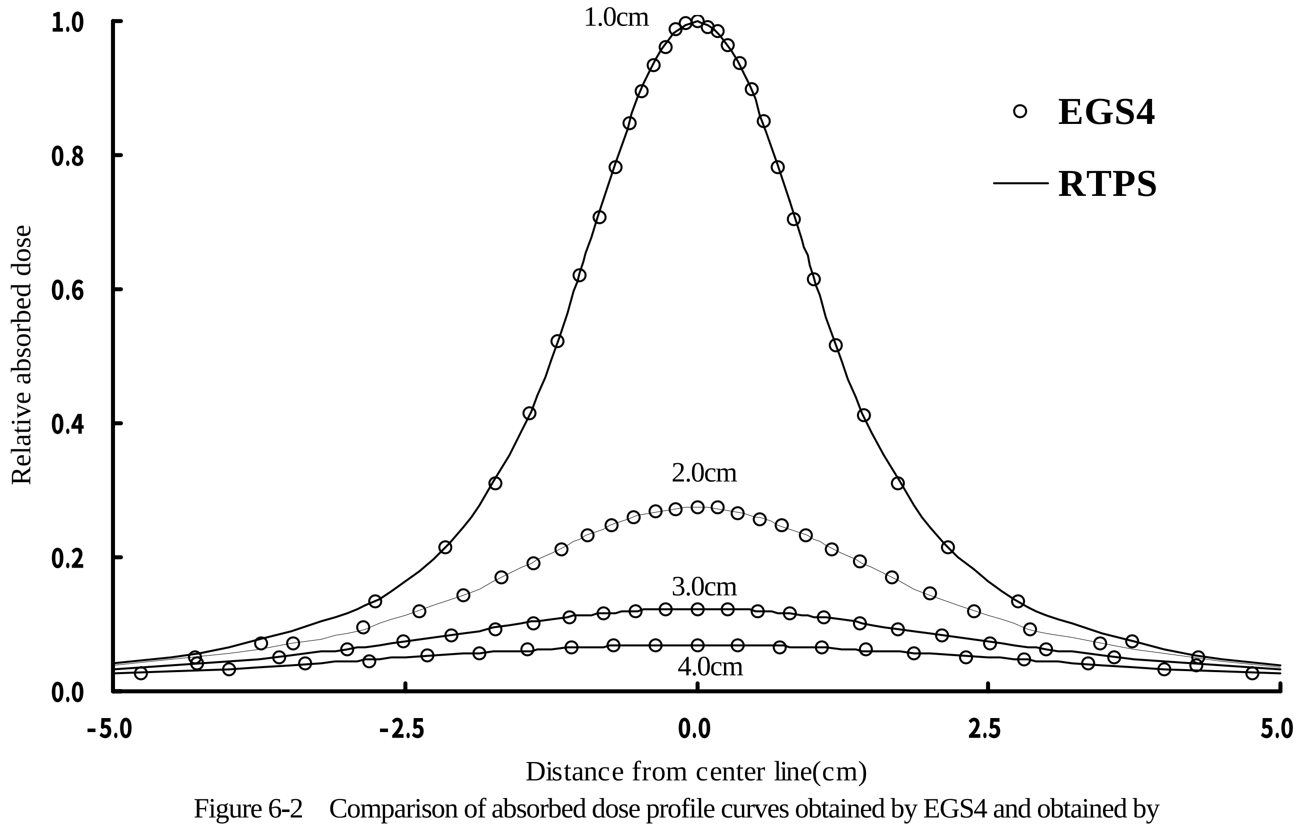


Figure 6-2　Comparison of absorbed dose profile curves obtained by EGS4 and obtained by RTPS (1.0-4.0cm).

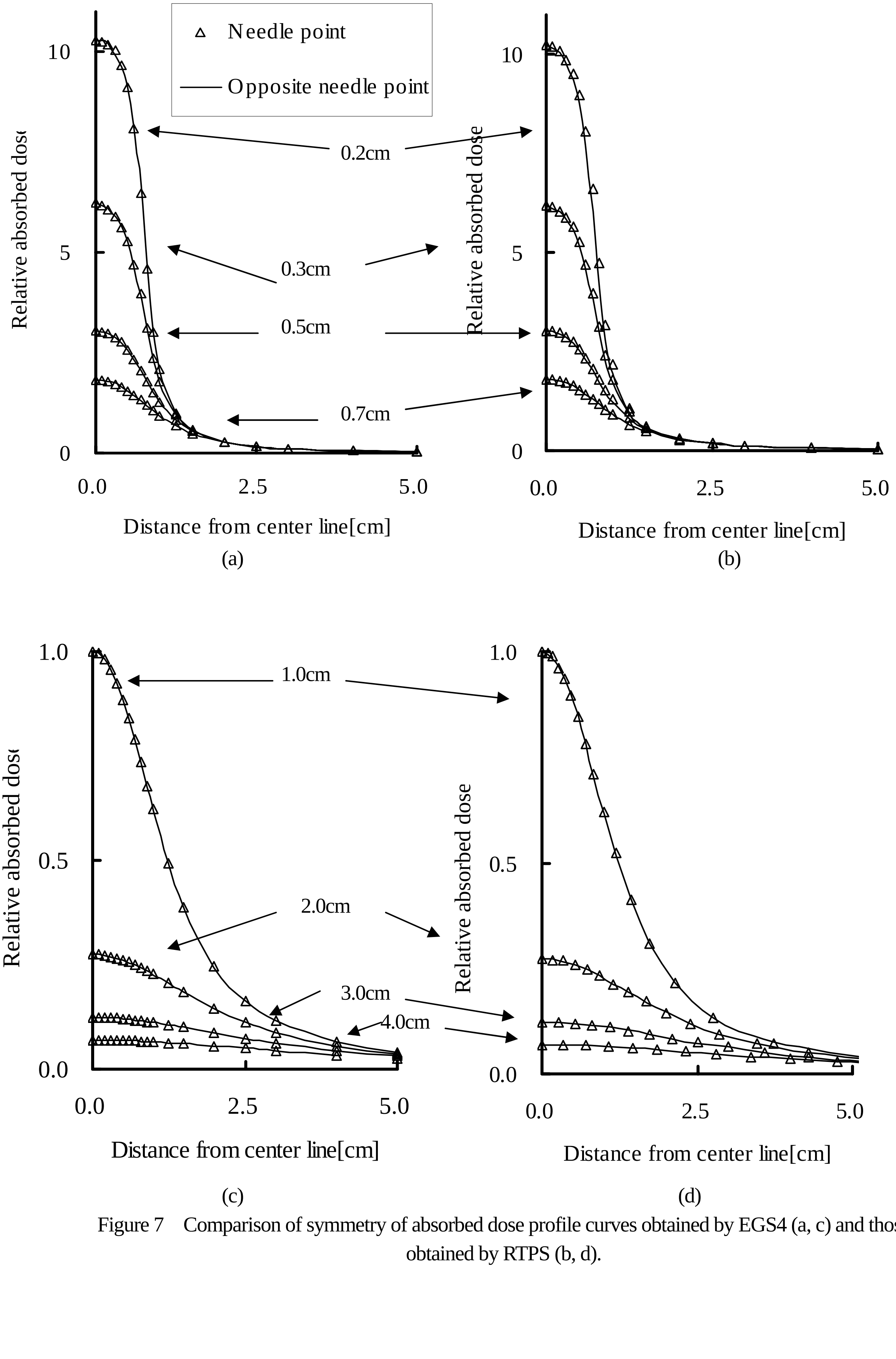


Figure 7 Comparison of symmetry of absorbed dose profile curves obtained by EGS4 (a, c) and those obtained by RTPS (b, d).