Determination of Target Point Magnification Rate on Stereotactic Angiography for Radiosurgery

—Technical Note—

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Abstract

We describe here a new method of calculating the target point magnification rate for radiosurgery by stereotactic angiography using a Leksell frame. As the distance (D) between the x-ray focus and the film plane is constant in each facility, the magnification rate (M) is determined by the equation: $M = D/[D/M_p + t]$, where M_p is the magnification rate of the proximal (to the x-ray focus) frame projected on the film plane and t is the distance between the proximal frame plane and the target point. The t value is given by the three-dimensionally determined stereotactic coordinates of the target point. Only the M_p value on the stereotactic angiogram must be measured. This method is theoretically more correct and has less risk of human error than the conventional, graphically determined method which necessitates measuring both the distal and proximal frame magnification rates. Furthermore, the inherent theoretical error of the conventional method is largest around the frame center, which is frequently selected as the target point for radiosurgical treatment, possibly causing serious error in accurate dose planning.

Key words: radiosurgery, gamma unit, Leksell frame, stereotactic angiography, magnification rate

Introduction

The magnification rate at the target point, determined on a stereotactic angiogram, is one of the most important dose-planning parameters for radiosurgery.¹⁾ Nowadays, modern microcomputer technology is widely used for the three-dimensional localization of the target point as well as the magnification rate.²⁾ Nevertheless, the graphical determination method is still important and useful, as it requires no special equipment. It is essential that two individuals make separate determinations to avoid human error. It is also advisable for the determination to be made by different methods; graphical and by microcomputer.

We propose a new method of calculating the magnification rate which is considered theoretically more correct and technically less complicated than

the conventional, graphically determined method generally used.

Method

Figure 1 schematically shows two coordinate frames, proximal and distal to the x-ray focus, projected on the film plane of stereotactic angiography using a modern Leksell stereotactic instrument (Model D or G; Elekta Instrument AB, Stockholm, Sweden).^{1,2)} The magnification rate at the target point located within the frame is a value between the two magnification rates, proximal (M_p) and distal (M_d), measured on the film (Fig. 2).

Figure 3 shows that M_p and M_d can be expressed as

$$M_p = D/d, M_d = D/[d + 18],^{1)}$$

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Fig. 1 Schematic drawing, showing projection of the coordinate system on the film plane. T: target point, t: distance between the proximal frame plane and the target point, X: left-right coordinate, Y: anterior-posterior coordinate, Z: superior-inferior coordinate.

Fig. 2 Lateral projection of a stereotactic angiogram, showing the magnification rate of the distal coordinate (Y) scale.

which can be converted to

$$D = 18 \times Mp \times Md / [Mp - Md],$$

$$d = 18 \times Md / [Mp - Md],$$

where D and d are the distances between the x-ray focus and the film plane and proximal frame plane, respectively. The distance between proximal and distal frames is 18 cm in this system.²⁾ In the same way, the magnification rate (M) at the target point is expressed as

$$M = D / [d + t],$$

where t is the distance between the proximal frame

plane and the target point. Therefore,

$$M = 18 \times Mp \times Md / \{18 \times Md + [Mp - Md] \times t\},$$

which can be applied whenever the D value is variable. In most facilities, however, D has a constant value (100 cm in the Karolinska Hospital, for example). Thus, this function can be also expressed as

$$M = D / [D/Mp + t],$$

where t is given as [real X (cm) - 1] in the lateral and [19 - real Y (cm)] in the frontal projection according to the true stereotactic coordinates of the target point as determined graphically or with a computer; the three-dimensional location of the target point is expressed as real [X, Y, and Z values] which correspond to left-right, anterior-posterior, and superior-inferior coordinate scales, respectively.

Results

To compare the magnification rate calculated by this method with the real magnification rate, an example with the distance between the x-ray focus and the frame center of 75 cm is discussed. This situation is frequently encountered in clinical practice. As the D value is fixed at 100 cm in the Karolinska Hospital and the Mp value is 1.515 ($Mp = 100/d = 100/66$), the t value-dependent magnification rate can be calculated by the equation:

$$M = 100 / [100/1.515 + t].$$

Fig. 3 Schematic drawing, depicting stereotactic angiography. D: distance between the x-ray focus and the film plane, d: distance between the x-ray focus and the proximal frame plane.

Table 1 Comparison of magnification rates calculated by the conventional and our methods with the real rate

Distance between the proximal frame plane and the target point (cm)	Real magnification rate	Calculated magnification rate (difference from real rate)	
		Present method*	Conventional method**
0	1.515 ⁺		
1			
2			
3			
4	1.429	1.428 (0.001)	1.443 (0.014)
5	1.408	1.408 (0.000)	1.425 (0.017)
6	1.389	1.389 (0.000)	1.407 (0.018)
7	1.370	1.370 (0.000)	1.389 (0.019)
8	1.351	1.351 (0.000)	1.371 (0.020)
9 (frame center)	1.333	1.333 (0.000)	1.353 (0.020)
10	1.316	1.316 (0.000)	1.334 (0.018)
11	1.299	1.299 (0.000)	1.316 (0.017)
12	1.282	1.282 (0.000)	1.298 (0.016)
13	1.266	1.266 (0.000)	1.280 (0.014)
14	1.250	1.250 (0.000)	1.262 (0.012)
15			
16			
17			
18	1.190 ⁺⁺		

The frame center is located 75 cm from the x-ray focus. * $M = 100/[100/1.515 + t]$, ** $M = 1.515 - [1.515 - 1.190] \times t/18$, where M: calculated magnification rate, t: distance between the proximal frame plane and the target point. ⁺Magnification rate of the proximal frame (Mp), ⁺⁺magnification rate of the distal frame (Md).

The calculated magnification rates differ by less than 0.001 from the real rates, as shown in Table 1, where the corresponding t value-dependent magnification rates ranging from 1 to 3 and from 15 to 17 have been omitted because they have no practical application.

Discussion

The magnification rate at the target point has conventionally been determined by the equation:

$$M = M_p - [M_p - M_d] \times t/18.$$

However, the relationship between M and t values is hyperbolic rather than linear, as discussed above, so the conventional calculation method is theoretically incorrect. Furthermore, differences between conventionally determined and real magnification rates are maximal around the frame center which is frequently selected as the target point for gamma unit treatment (Table 1). In contrast, the calculation method described here is not only theoretically correct but also simple; all that is required is measurement of the Mp value on the stereotactic angiogram because the D value is a constant distance in each facility. The conventional method requires measurement of both Mp and Md values, increasing the risk of human error. Although the difference, 0.02, between the conventionally calculated and real rates is relatively small, this inherent theoretical error can be augmented by

human error. When treating a lesion larger than 3.3 cm in diameter, a difference of 0.3 or more can result in an underestimate as significant as 1 mm in comparison with the real size. Because of the theoretical inaccuracy of the conventional method, we suggest that it should not be used for any procedure requiring meticulous dose planning.

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