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Determination of Target Position with BRW Stereoatic Frame in non-orthogonal CT scans

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Abstract

Stereotactic implantation of intracranial lesions, and the development of stereotactic convergent irradiation, radiosurgery, techniques have to obtain the accurate coordinates of the tumor locations and that of critical organ.

Computed tomography(CT) provides relatively precise imformations of tumor localization and surround the normal organs for conventional radiotherapy. This CT image use to extend for stereotactic radiosurgery procedures. Since the convergent irradiation technique in linear accelerator requires the target center coincident with gantry isocenter or radosurgery frame, the target coordinates must be described in accurately.

We used the BRW stereotactic system for describing the target position in CT images.

This algorithm provides the coordinate conversions for orthogonal or non-orthogonal CT scan image.

In this experiments, the target positions have shown the small discripancy within ±0.3㎜ uncertanty in several known target positions in the phantom through the provided programs and it compared to that of BRW stereotactic systems.

Key words: Coordinate Transform, BRW system, linear accelerator

INTRODUCTION

It is well known that the stereotactic radiosurgery is principally a focal beam irradiation to small intracranial tumor that delivers a high dose in a single fraction to stereotactically positioned in brain volume.

Recently, several authors[1, 2)] have been used to guide in the precise biopsy or implantation of radioactive sources in brain tumors using the BRW stereotactic

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localizer system.

Since the stereotactic convergent irradiations have been required an accurate target position, we will describe in detail the target position in actually non-orthogonal CT scan image.

In order to get an accurate target position the coordinate of tumor center in CT image must be transformed to that of the radiosurgery frame in high accuracy.

However, Implementation of linear accelerator based on radiosurgery has been limited in part by lack of suitable program for acquisition of target coordinate in practical non-orthogonal CT scans.

In this work, we present in detail the algorithm for coordinate transforms from BRW localizer ring in non-orthogonal CT image to radiosurgery frame in high accuracy.

MATERIALS AND METHODS

COORDINATE TRANSFORMATION

BRW stereotactic localizer ring was used to obtain the target informations in CT image. Landmark of the BRW stereotactic system seen on CT images are produced by scanning the localizer ring that is mounted to head ring which was fixed to the patient's head with 4 fiducial pins.

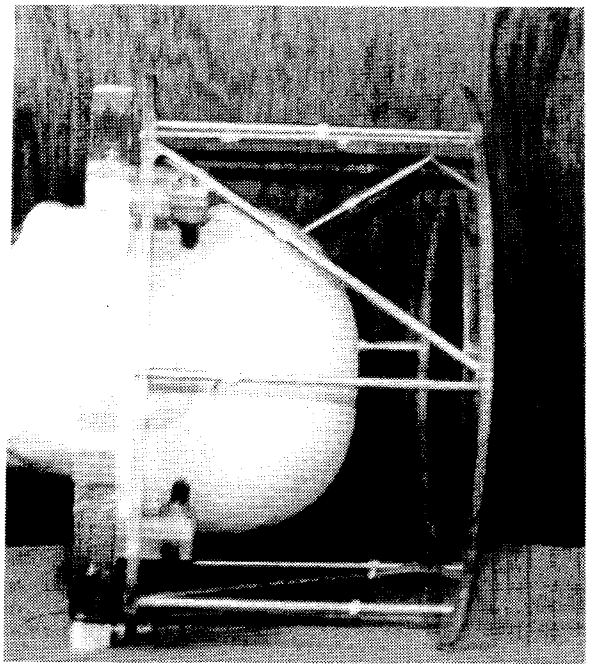

Fig. 1. Figure of BRW Localizer Ring and Coordinates of Pins.

The localizer ring has six vertical rods equally spaced and three diagonal carbon fiber rods, forming N-shaped configurations as shown in Fig. 1. It attaches to the head ring[3)].

When the CT scan intersects the carbon rods, they appear as nine index or fiducial marks on the CT images. The dimension of the coordinate system are expressed in mm. The vertical rod with the largest diameter, labeled as 1 in Fig. 1. is used to identify the right side of the partinet's head, but the landmark of that presents on left side of CT image as the patient position is supine.

Here, the BRW coordinate system is set up with the postive X axis passes through labeled 6th rod caused by the coordinate frame based on CT image is usually displayed the axial view to reverse for facing to patient as shown in Fig.2.

The coordinate system is set up with the orgin positioned at the intersection of the line draw between opposing pins on the CT images. Y axis was presented the distance, depth, from base head ring to target plane, Z axis is to set toward direction of face to get right hand coordinate system.

The XZ plane represents the axial view in CT images and Y axis is obtained by table movement during scans.

In order to directly use the CT image to convert the coordinate to radiosurgery

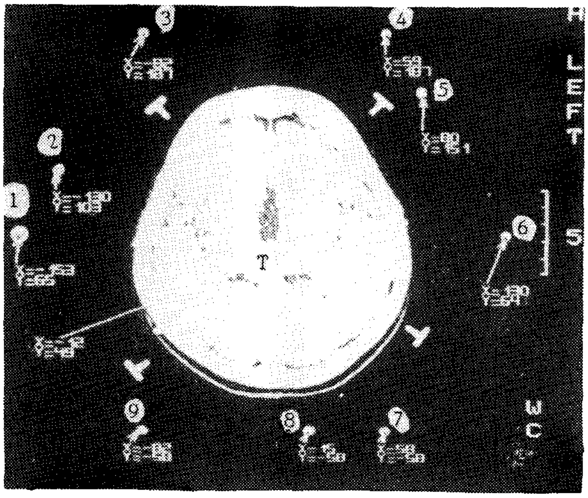

Fig. 2. Typical CT image and intersected coordinates of BRW Localizer Ring

frame, the intersection of the BRW is true orthogonal to CT coordinate system. However, it is difficult to get the orthogonal CT image caused by table band and time consumptions in practice.

We can get the orthogonal coordinates through the coordinate transform and vector analysis in non-orthogonal CT image.

Transformation coefficient between BRW and CT coordinate can be determined from the relative positions of nine pins. According to the geometric consideration, the depth from head ring is calculated easily with slanted rods of BRW frame as follows;

$$X_2=D[(s/S)\cos 60-1]$$
$$Y_2=(s/S)\ H$$
$$Z_2=(s/S)\ D\sin 60$$
$$X_5=D\{1-[1-(s/S)]\cos 60\}$$
$$Y_5=(s/S)\ H$$
$$Z_5=[1-(s/S)]\ D\sin 60$$
$$X_8=D[1/2-(s/S)]$$
$$Y_8=(s/S)\ H$$
$$Z_8=-D\cos 30 \quad \cdots\cdots (1)$$

where s, S are the distance from vertical rod to slanted rod in CT image and to other vertical rod, respectively.

And D, H are the actual distance of 140mm form vertical rod to other vertical rod and 189mm of heighte of BRW localizer ring, actually this height represents the distance from head ring to tip of slant[4].

We can determine the depth from head ring with Y distance as equation(1) and Y_is are all same in true orthogonal intersected images however it will be became a different value in non-orthogonal scan images.

The coordinates of labeled S_{13}, S_{14}, S_{17}, S_{19}, in first CT image and those of second one makes a rectangular coordinate system in space and let i, j, k be unit vectors along the positive N_x, N_y, axis, respectively as shown in Fig.3. X, Y and Z-axis are presented the rectangular coordnate system in CT scan image of right-angled intersection, The plane vector N_x, can be obtained from the plane of S_{29} and S_{13} by vector product.

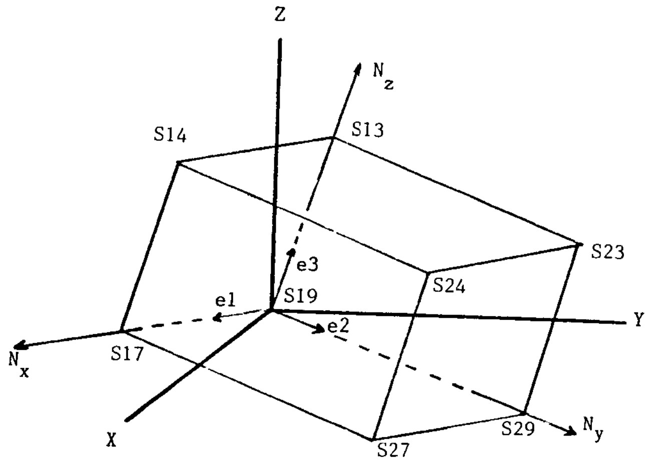

Fig.3. Cartesian Coordinate and Direction Cosine of Intersected Localizing Rods in Computed Tomography

The direction cosines of N_i which vector $N_i = X_i + Y_j = X_k$ can be obtained from:

$$l_i = X_i / |N_x|, \quad i=1, 2, 3$$
$$m_j = Y_j / |N_r|, \quad j=1, 2, 3$$
$$n_k = Z_k / |N_z|, \quad k=1, 2, 3 \quad \cdots\cdots (2)$$

where i, j, k is unit vector of axis of rectangular coordinate system.

We can obtain the orthogonal coorinate system through the multiple of rotation vector, that is

$$R = \begin{pmatrix} l1 & m2 & n1 \\ l2 & m2 & n2 \\ l3 & m3 & n3 \end{pmatrix} \cdots\cdots (3)$$

The rotated coordinates are obtained with follows:

$$X_{ijk} = R\ X_{ijk} \cdots\cdots (4)$$

We can determine the target position X, Z from CT image using above rotation vector but yet the depth from origin is not explicity present.

The intersection of slanted rods makes a plane as shown in Fig.4 in orthgonal or not. We can make a vertical vector N of plane from vector A and B of intersect plane.

Fig.4. shows the relation of BRW localizer frame to spartial coordinate system, the intersection plane containes the target point T (x, z), and the projection of T to XZ plane shows as P(x, y, z).

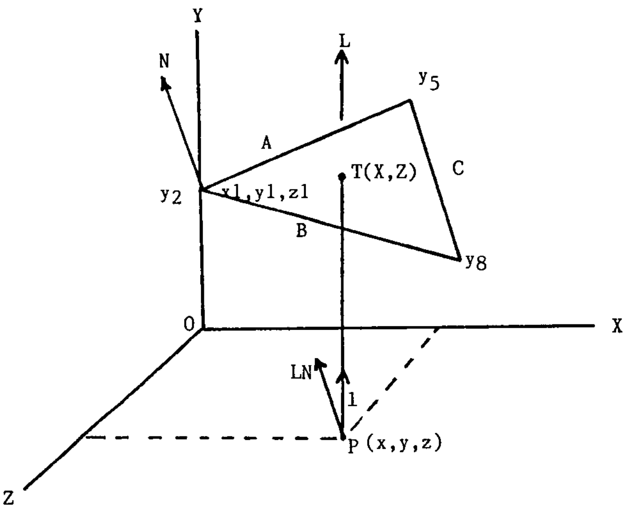

Fig. 4. Plane of Oblique Scan Image and Intersected Rods(y_2, y_5, y_8)

The vector N and its unit are obtained from cross product of vector A and B. as shown in Fig.4. The depth can obtained from scalar product of L and LN which is a vector of point P to Y_2.

EXPERIMENTS

The small radio-opaque material, 2mm of diameter x 2mm in length of aluminium cylinder, for dummy target was inserted in a tip of the plastic holder in BRW localizer ring under known coordinates and scanned it with non-orthogonal intersection of the target as shown in Fig.5.

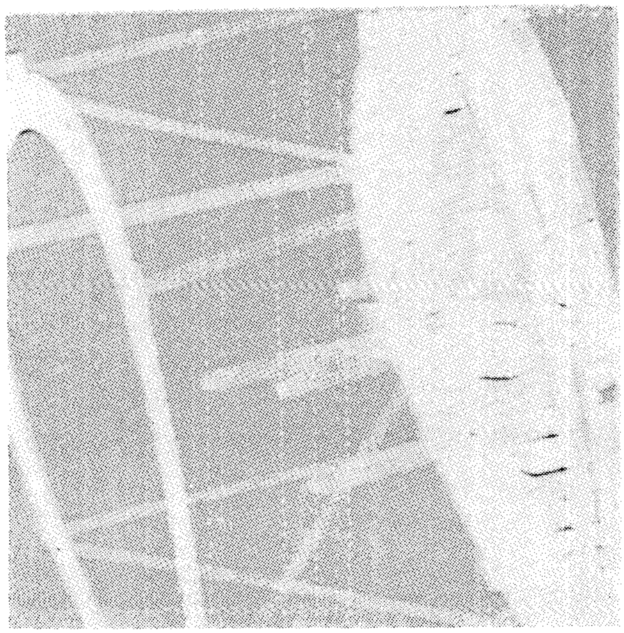

Fig.5. A typical topography showing the stereotactic frame and phantom targets in a non-orthogonal intersected CT image.

The matrix of reconstructed of image was 512×512 with 4mm of slice thichness in SOMATOM DRH(Siemens, Germany).

The coordinates of small dummy target are list in first colum of ~~table~~ 2 and those of 9 pins in Ct images are also list in Table 1.

The location of dummy target was investigated with vernier caliper in X, Y and Z distance from reference of head ring base.

Especially, the dummy target were mounted on 20mm diameter of cylindrical lucite rod and the coordinates of dummy positions were measured with vernier caliper in directly from bottom of plate.

Table 1. The Coordinates in mm of 9 Pins of the BRW localizer ring in Non-Orthogonal Intersectio

number of	1st scan			2nd scan		
pin	X	Y	Z	X	Y	Z
1	-129	0	82	-128	49	78
2	-83	0	156	-102	49	122
3	-58	0	201	-58	49	200
4	83	0	200	83	49	200
5	125	0	125	107	49	157
6	152	0	78	152	49	78
7	81	0	-43	83	49	-43
8	-43	0	-41	35	49	-42
9	-58	0	-40	-58	49	-43
T	-23	0	57			

*T represents the dummy target

RESULTS

The computation algorithm for coordinates of small target in BRW localizer ring was derived from transtormation coefficient coordinate transformation and vector analysis in non-orthogonal CT scans.

In our study, the localizer ring lies on CT table with arbiturary angles for non-orthogonal intersection as shown in Table 1 and compared to BRW provide as shown in Table 2. It shows that coordinates of our computation model has more closed to that of actual positions(mm). We provided the 12 different positons in stereotactic localizer ring, the average discripancies have showed as -0.006±0.29, 0.02±0.38 and -0.006±0.40 for X, Y and Z in our computation model, respectively. But -0.3±0.43, 0.64±0.47 and -0.3±0.28 in BRW provided, respectively with same coordinates.

It is well known the distance from number 3 of pin of BRW localizer ring to 9 of that is 242.5mm and 1 to 6 of that makes 280mm in orthgonal CT scans. In our study, the indication of coordinates in CT image was performed with style pen for cursor and it can be induced the ±1mm uncertainty in 512×512 matrix of scan parameter.

DISCUSSIONS

Recently, stereotactic radiosurgery and implantation of radioisotope are top issued in medical physicist, radiation oncölogist and neuroscientist[5]. These technique require the accurate coordinate of target surrounding the critical normal organs.

Many authors used the BRW system for neurosurgery or stereotactic radiosurgery[2, 3, 6], However, the evperimental detemination of target position in non-orthogonal intersection of interesting area is relative small.

Some interest has been shown in the stereotactic transformation algorithm[7]. The software available is rather complex. Furthermore, listings of the algorithm are not made available by the manufactures. Saw et al[2] and Lulu[7] showed the coordinate transformation for stereotactic systems in orthogonal intersection.

Practically, it is difficult to patient set up orthogonal to the axis of computer tomographic scanner caused by time consumptions and deficit of patient table-gantry calibration in CT unit.

In this study, the determination of the coordinates of rods in CT screen was maximum induced the ±1mm discripancy with style pen cursor. It can be easily shown at the transformed coordinates in drawing the line of two slices. We provided the transformed coordinates of rods were to be displayed on screen of personal computer for investigation of original coordinates.

In our experiments, patient CT table was about 2° bent to downward in 1 meter of stretched. There is no need to fix the BRW localizer ring when our model is adapted to get the target localization.

We can determine the coordinate of target with high accuracy in non-orthogoanl intersection of CT scan as shown in Tabel 2.

It has shown the averge 0.02±0.38mm discripancy but maximum error has revealed to 0.6mm.

Brown et al[8] have reported the worst-case error distance was 1.8mm with BRW system in his alogrithm and experiments which was similiar to this study. But they used one CT image for depth calculation.

Target No.		actual coordinate	BRW	authors
	X	35.0	34.8	34.7
1	Y	97.0	97.5	96.7
	Z	-20.0	-20.2	-19.8
	X	-18.0	-18.4	-18.2
2	Y	117.0	118.0	117.2
	Z	-35.0	-35.1	-35.2
	X	-35.0	-35.2	-34.8
3	Y	117.0	118.2	117.6
	Z	-22.0	-22.8	-22.7

We consider this algorithm can be also extended to biopsy and other implantation of radioisotope in intracranial lesions.

CONCOLUSION

The coordinates of target in stereotactic frame was investigated with small target(2mm ϕ) in radio-opaque material with cylindrical lucite rods.

We have derived the coordinate transformation for obtaining the target center with BRW stereotactic localizer ring in non-orthogonal intersect.

Computed for a given localization of dummy target in localizer ring was performed with very high accuracy in 0.02 ± 0.38mm for depth, 0.06 ± 0.29mm for X and -0.06 ± 0.40mm for Z calculations.

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비직교성 전산화단층촬영에서 뇌정위수술용 좌표계를 이용한 표적위치 결정

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초 록

최근 두개부 종양의 방사성물질의 자입과 방사선입체조사에 의한 뇌수술이 개발되어 의료계에 많은 관심을 끌고 있다. 또한 방사선수술등은 비관혈적인 체외조사이므로 뇌정위수술용 좌표계의 전산화단층촬영을 이용한 표적중심결정이 매우 중요하다.

현재 알려진 방법은 뇌정위수술용좌표계의 전산화단층촬영에 대한 직교성하에서 비교적 정확하게 표적의 위치를 결정하게 되나, 임상현장에서 직교성유지는 실제 어려운 실정이다.

이에 필자들은 임의의 비직교성 스켄하에서 정확한 표적좌표를 얻기위한 알고리즘을 사용하였으며, 표적오차는 평균 0.02±0.3㎜를 보였다.