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R E Latchaw, L D Lunsford and W H Kennedy

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# Reformatted Imaging to Define the Intercommissural Line for CT-Guided Stereotaxic Functional Neurosurgery

Richard E. Latchaw[1,2]
L. Dade Lunsford[1,2]
William H. Kennedy[1]

**Functional stereotaxic neurosurgery has traditionally required definition of the line between the anterior and posterior commissures as the basis for defining the target site for a procedure such as stereotaxic thalamotomy. While axial computed tomographic (CT) imaging precisely defines the third ventricle and the commissures, the planes of the axial images are not necessarily parallel to the important intercommissural line. A technique is described in which coronal oblique reformations are obtained, with the reformations passing through both the anterior and posterior commissures. Stereotaxic coordinates of the target obtained from this reformatted image are directly transferable to the CT-compatible Leksell frame. Both imaging and surgery are performed on the scanner, which is located in an operating room especially designed for CT-guided surgical procedures.**

Computed tomography (CT) has revolutionized stereotaxic neurosurgery [1–3]. Because current high-resolution scanners have a spatial resolution of 0.5–0.75 mm, precise definition of a target is now possible. In addition, the target may be related to anatomic pathways such as the internal capsule, which can be demonstrated exquisitely with CT. Stereotaxic neurosurgery may be divided into morphologic stereotaxis (e.g., tumor biopsy, cyst drainage) and functional stereotaxis (e.g., thalamotomy, electrode implantation). The need for accuracy to perform functional stereotaxic neurosurgery is obviously greater, since the location of a small, normal anatomic target must be determined.

Functional stereotaxis has traditionally relied on imaging the anterior and posterior commissures, and target position has been related to the intercommissural line. Less often, the line between the foramen of Monro and the posterior commissure has been used. These structures have been demonstrated by air or positive-contrast encephalography of the third ventricle either preoperatively or at surgery. Pooled anatomic data from cadaver specimens has been used to define the relations of targets such as thalamic nuclei to the anterior and posterior commissures and the intercommissural line. Atlases have been composed, demonstrating the relation of various anatomic structures to the important intercommissural line [4].

While CT is able to define the position of gray-matter nuclei and white-matter tracks with a high degree of precision, it is still not possible to define the position of a target within the deep gray-matter or white-matter tracks without reference to the intercommissural line. The plane of CT scanning is usually not parallel to the intercommissural line, and the plane of the intercommissural line cannot be predicted from the external anatomy of the skull. The solution to the problem lies in the production of reformatted images in the plane and parallel to the plane containing the intercommissural line, allowing precise localization of a target. We are now able to create a coronal oblique reformatted image that either contains or is parallel to this intercommissural line. We will discuss the techniques used in producing this coronal oblique image and illustrate the use of these techniques in functional stereotaxic neurosurgery.

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[1] Department of Radiology, Division of Neuroradiology, University Health Center of Pittsburgh, M-260 Scaife Hall, Pittsburgh, PA 15261. Address reprint requests to R. E. Latchaw.

[2] Department of Neurological Surgery, University Health Center of Pittsburgh, Pittsburgh, PA 15261.

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## Materials and Methods

We use a General Electric 8800 CT/T Scanner (GE Medical Systems, Milwaukee) for our stereotaxic neurosurgical procedures. In our institution, such a scanner is located in an operating room and allows all scanning and stereotaxic neurosurgery to be performed under sterile conditions on the scanner without moving the patient [5]. Scanning is performed with the Leksell CT stereotaxic frame (AB Elekta Instruments, Stockholm) attached to the head by carbon fiber pins. Low-atomic-number materials used to construct this frame allow scanning with minimal artifacts. The Leksell coordinate frame can be applied to the head at any angle. Once applied, however, all CT scans are obtained parallel to the frame base, and the CT gantry is not angled. This reduces reformation time. All coordinates from the CT scan matrix are directly transferable to the coordinates of the frame [1, 2, 6]. Surgery is performed in the CT scanner, and scans may be obtained with the stereotaxic probe in position [7]. CT imaging immediately after the procedure ensures anatomic accuracy of probe placement and identifies potential complications such as hemorrhage.

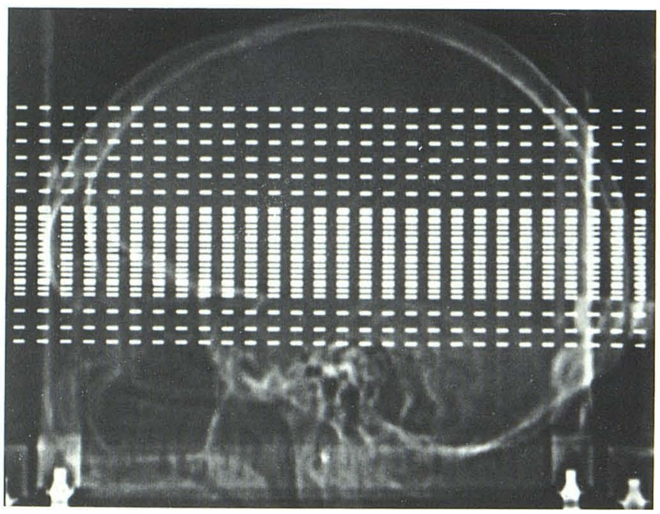

Fig. 1.—Localization of scans. Lateral scout view image of head with patient in stereotaxic frame. Eighteen cuts have been obtained through entire height of third ventricle, with 5 mm cuts spaced above and below to demonstrate relations of third ventricle to contiguous neurologic structures on reformatted images.

Contiguous 1.5 mm cuts parallel to the frame base are obtained through the diencephalon to the level of the velum interpositum. Contiguous 5 mm cuts are obtained for about 2 cm both above and below the 1.5 mm slices so that reformatted images of the third ventricular region may be related to contiguous anatomic structures (fig. 1). Scanning is performed at 120 kVp, 600 mA, 9.6 sec (1.9 sec actual "tube-on" time × 600 mA = 1152 mAs), using the small body mode.

The ARRANGE program (General Electric Medical Systems, Milwaukee) allows the production of reformatted images in multiple projections, including the sagittal, coronal, paraxial, and coronal oblique projections. A coronal oblique projection of the head is a plane at an angle to the orbitomeatal line. While sagittal and coronal imaging have traditionally been used in the diagnosis of central nervous system abnormalities, the paraxial and coronal oblique images have greater therapeutic than diagnostic usefulness. By selecting a point relatively anterior in the head on one slice and a posterior point on a second slice, a coronal oblique image passing through both points is produced. This reformatted coronal oblique image is angled relative to the original plane of scanning, but has spatial resolution very similar to the original slices. The ARRANGE program allows direct movement from one reformatted projection to another. For example, one may move from a coronal oblique projection to a sagittal projection or from sagittal to coronal oblique.

Two methods are used for the definition of the intercommissural line. The first begins with the identification of the posterior commissure on a cut through the third ventricle and the identification of the anterior commissure on an inferior or superior cut (figs. 2A and 2B). The levels of the anterior and posterior commissures are used as the two points defining the coronal oblique plane (fig. 2C). The coronal oblique image is then generated and the intercommissural line is drawn between the commissures. This line defines the plane of a sagittal reformatted image that may be subsequently generated.

While the posterior commissure is relatively easy to identify on axial images, it may be more difficult to identify the anterior commissure. Therefore, a second method may be used to define the intercommissural line. A midline sagittal reformatted image may be obtained, with identification of the anterior and the posterior commissures on that sagittal reformation. The intercommissural line is drawn

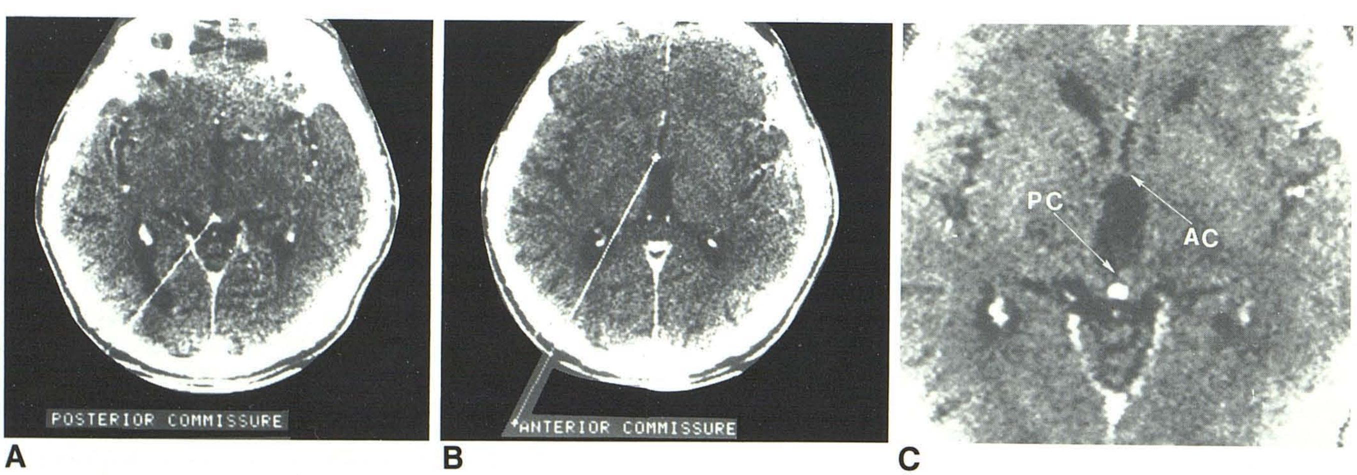


Fig. 2.—Production of intercommissural plane from axial images. Original cuts through posterior commissure (**A**) and anterior commissure (**B**) are used to produce image parallel to intercommissural plane (**C**), a coronal oblique reformatted image passing through both anterior (AC) and posterior (PC) commissures.

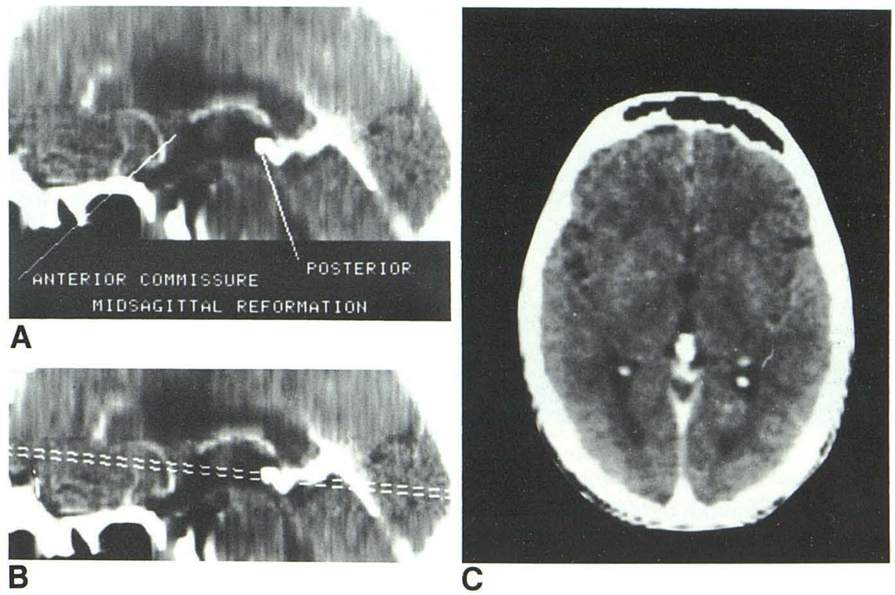


Fig. 3.—Production of intercommissural image from the midsagittal reformation. Alternative method of producing coronal oblique image parallel to intercommissural plane requires midsagittal reformation. Initial axial cuts through third ventricle are used to produce midsagittal reformation. Anterior commissure is imaged just below foramen of Monro on midsagittal image, while posterior commissure is located just inferior to calcified pineal gland (**A**). A 5-mm-thick oblique reformatted image through these two points (plane is shown in **B**) is seen in **C**.

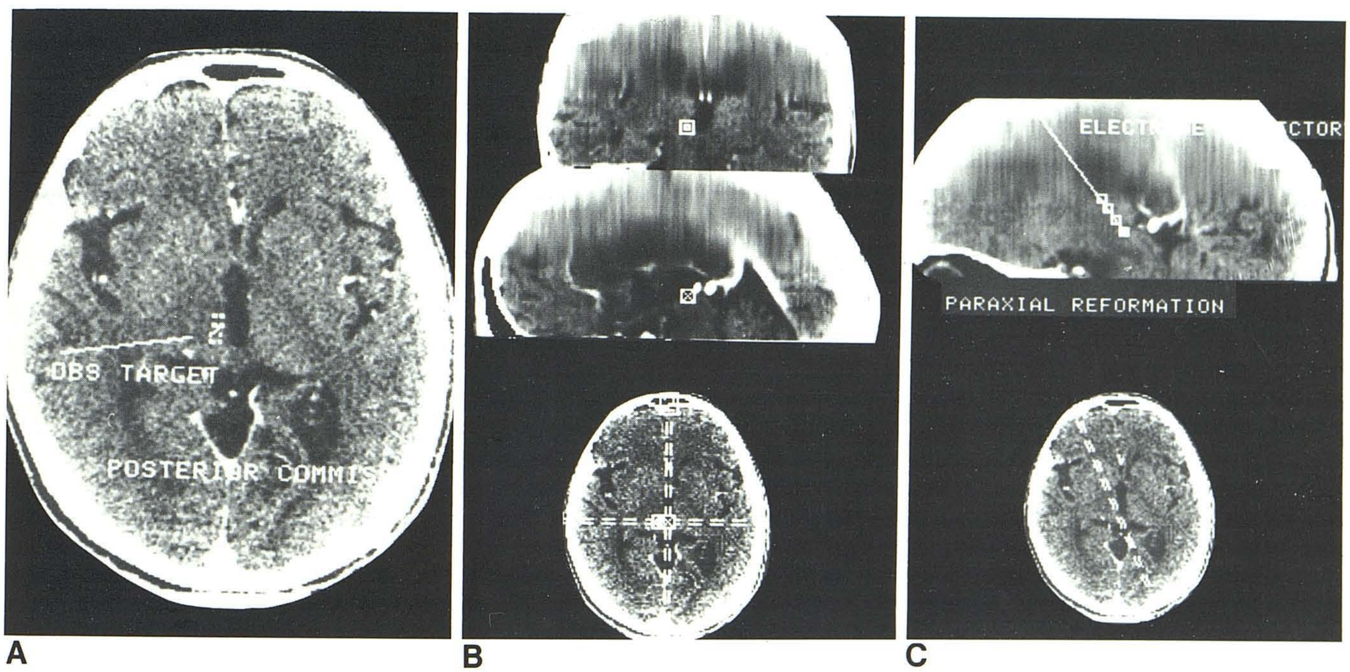


Fig. 4.—Determination and demonstration of target point and electrode trajectory for deep brain stimulation. In an effort to ameliorate chronic pain, a target point below the wall of the third ventricle in the plane of the posterior commissure may be stimulated with transparenchymal electrode. **A**, Coronal oblique image through plane of both anterior and posterior commissures. Target for deep brain stimulation (DBS) may be measured directly. Target site is demonstrated on coronal and sagittal reformatted images (**B**). Path of electrode, neural structures through which it must pass, and one or more target sites may be demonstrated on paraxial reformation (**C**).

and the coronal oblique image is produced in the plane of that line (fig. 3). Once a coronal oblique image in the intercommissural plane is obtained, a plane above or below but parallel to the plane may be obtained. Planes as close as 1 pixel (0.8 mm) may be produced. In addition, in order to select other deep brain targets, a plane may be produced parallel to and a given distance above or below the intercommissural plane by knowing the pixel height (0.8 mm).

Whichever method is used to produce an image in the intercommissural plane, measurements are made from the intercommissural line to determine the exact location of a target. For example, measurements to various parts of the internal capsule or to deep gray-matter nuclei may be made (fig. 4). Measurements may be made from the lateral walls of the third ventricle to the internal capsule in order to determine the width of the third ventricle and the exact location of a thalamic nucleus (fig. 5).

Sagittal and coronal reformatted imaging of the target location may be performed (figs. 4 and 5). The depiction of targets such as points of electrode placement may be made on the sagittal or coronal

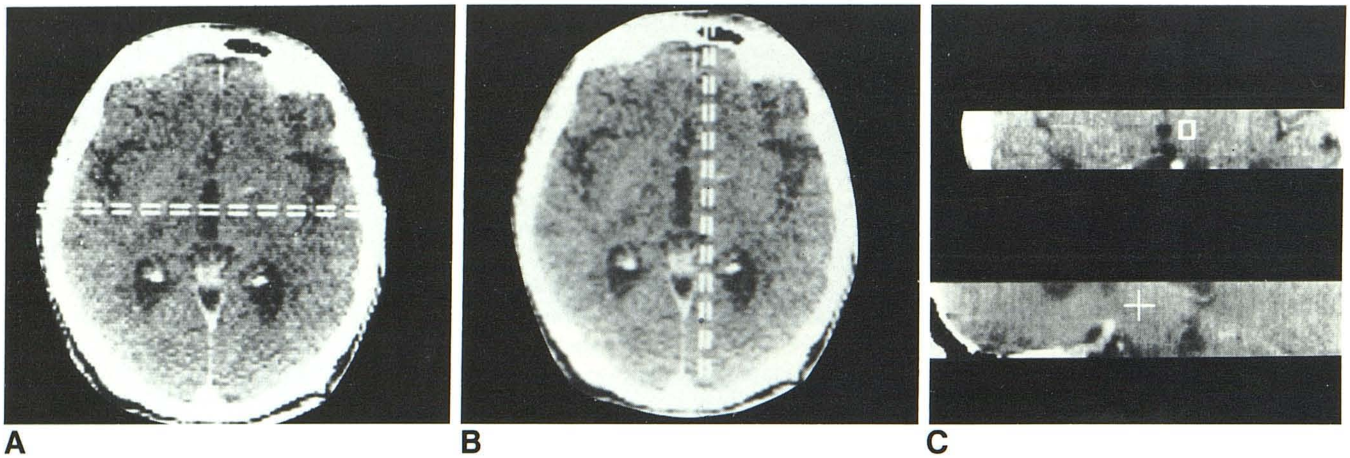

Fig. 5.—Determination and demonstration of thalamotomy site on coronal oblique, sagittal, and coronal reformatted images. **A** and **B** are coronal oblique reformatted images in intercommissural plane. Target for thalamotomy may be measured directly, taking into consideration width of third ventricle. Coronal (**C**, *top*) and sagittal (**C**, *bottom*) reformatted images of target site and its relation to surrounding structures are demonstrated.

projections or on a paraxial reformation if the plane of a series of targets is at an angle to the anteroposterior midline (fig. 4). The trajectory of the probe, and all structures encountered by the probe, may be demonstrated on a reformatted image in a plane that includes the point of intracranial insertion of the probe and the target site (fig. 4).

Although the spatial resolution of the system is 0.75 mm and although the techniques described above offer a high level of accuracy in the anatomic identification of a target, electrophysiologic measurements in each patient must be used to confirm accurate target determination. During thalamotomy performed for treatment of movement disorders such as Parkinson disease, direct thalamic recording of neural noise [8], stimulation of the target area to assess augmentation or suppression of tremor [9], and evoked response measurements characteristic of various thalamic nuclei [10, 11] have been used to determine the physiologic target. After selection of the target by these techniques, we have found it unnecessary to reposition the probe in the anteroposterior (Y) or left-right (X) coordinates, but superoinferior (Z) movement of the probe tip in the trajectory selected by CT is often necessary. This coordinate, which is dependent on CT slice thickness, is most sensitive to error and requires electrophysiologic testing to match the anatomic and physiologic target.

## Discussion

CT scanning for morphologic stereotaxic neurosurgery has provided a very accurate method for the biopsy of intracranial masses, the drainage of cysts, and the instillation of therapeutic agents [2, 3]. Functional stereotaxic neurosurgery has gained even more from the addition of CT, since the targets are extremely small and accuracy in the order of less than 1 mm is mandatory. The GE 8800 CT/T scanner has a spatial resolution of 0.6 mm with target reconstruction.

While CT recognition of the internal capsule defines the lateral and inferior margins of the thalamus, specific thalamic nuclei still cannot be differentiated. It becomes necessary to identify the intercommissural plane, the standard deep brain reference marker for functional stereotaxic neurosurgery. The techniques we describe permit identification of this reference line without the need for encephalography. Early in our experience using CT scanning localization of a target, we compared positive-contrast encephalography with CT localization in three patients. Variations in target selection were no greater than $\pm 0.5$ mm in each coordinate. Our subsequent procedures done with CT localization have had only physiologic confirmation of the target area as well, requiring probe position variation only in the Z coordinate. We have since abandoned preoperative or intraoperative encephalography as no longer necessary.

Many thin CT slices are needed to ensure adequate spatial resolution in the reformatted images. We use contiguous 1.5 mm cuts, but 5 mm slices incremented every 2–3 mm could be used also. The coronal oblique and sagittal reformations used in the definition of the intercommissural line may be made up to 5 pixels thick to decrease the noise in the reformatted image. There is always a trade-off in the signal-to-noise ratio and spatial resolution with a given amount of radiation and slice thickness. For the accurate identification of a target and measurement from specific reference points, signal-to-noise ratio is less important than spatial resolution. Stereotaxic accuracy based on CT imaging has remained least accurate in the superoinferior patient coordinate (Z plane), since it is dependent on slice thickness. Reduction in slice thickness to 1.5 mm improves accuracy. Fortunately most stereotaxic lesions (e.g., movement disorder surgery) must extend 6–9 mm in the two planes to achieve effect. Critical accuracy is required for creating the lesion but at the same time sparing the surrounding internal capsule, which is lateral and inferior to the diencephalon.

Scanning through the third ventricle with contiguous 1.5 mm slices usually requires 15 to 25 cuts. In addition, there may be four or five 5 mm slices above and a similar number below the contiguous 1.5 mm cuts. The radiation dose to the lens of the eye with this many cuts, assuming 1152 mAs, is about 9 rad (0.09 Gy). While this may seem to be a relatively high dose, pneumoencephalography with tomography traditionally gave high doses in the order of 15–20 rad (0.15–0.2 Gy). The scanning time for the multiple contiguous cuts is relatively fast, about 20–25 min when allowing time for x-ray tube cooling. The time to produce the reformatted images is reduced by scanning with no gantry tilt. Typically, the time required for production of the reformatted coronal oblique and midline sagittal images, once scanning actually has been performed, is 3–4 min.

Using the CT images and scanner software, distance measurements can be related both to the intercommissural line and to the thalamic width [6]. The position of a particular target such as a thalamic nucleus varies slightly among patients; absolute correlation between the third ventricular width and height and the associated thalamic width has not been confirmed [11]. Since the lateral margin of a correctly placed thalamic lesion for tremor abuts on the internal capsule, demonstration of the internal capsule by CT has provided very important additional data in safe target selection.

The use of neurophysiologic confirmation must be stressed. The anatomic differences from patient to patient and the inability to image actual nuclei by CT mean that specific measurements to a particular nucleus, as derived from pooled data, may be inaccurate in a given patient [11]. The spatial resolution of the CT-guided stereotaxic system is extremely fine, and the techniques we describe further refine the accuracy of CT-guided functional stereotaxic neurosurgery. Such accuracy, however, is overcome by individual patient variation and the relatively wide range within anatomic data. Therefore, neurophysiologic evaluation must be performed once the probe is in place to confirm anatomic accuracy. Morbidity after stereotaxic thalamotomy is related to incorrect physiologic target selection and to the size of the lesion created [8]. Morbidity may be as high as 30%–40% if neurophysiologic corroboration of the anatomic target is ignored [12]. No complications of either the imaging or the surgical parts of the procedure have occurred in our experience with CT localization followed by electrophysiologic confirmation of the target site (20 patients).

Several investigators have digitized stereotaxic atlas templates of the thalamic nuclei to overlay CT images [13, 14]. These templates can be expanded or contracted proportional to the size of the third ventricle. Using our techniques for the definition of the intercommissural line and the direct demonstration of the third ventricle, internal capsule, and other anatomic structures, the need for such templates is greatly reduced. Measurements may be made directly from imaged structures and defined reference lines; each patient's own brain serves as a stereotaxic atlas.

Thin-section magnetic resonance (MR) scanning has the potential to actually image individual thalamic nuclei [15]. Therapeutic techniques such as stereotaxic neurosurgery are already being adapted to MR systems, although distortion of the homogeneous magnetic field by the stereotaxic device is still a problem. In addition, superior MR images require close application of the radiofrequency coil to the body part to be imaged, which as yet remains difficult in the presence of a stereotaxic frame. Perhaps measurement and definition of reference points and lines such as the intercommissural line will be obviated by MR. At present, CT guidance, with the use of new algorithms for the production of images in the plane of a target and the definition of specific reference lines and points, provides excellent accuracy for functional stereotaxic neurosurgery.

## REFERENCES


1. Lunsford LD. Innovations in stereotaxic technique coupled with computerized tomography. *Contemp Neurosurg* **1982**;4:1–6
2. Lunsford LD, Rosenbaum AE, Perry J. Stereotactic surgery using the "Therapeutic" CT scanner. *Surg Neurol* **1982**;18:116–122
3. Lunsford LD, Martinez AJ. Stereotactic exploration of the brain in the era of computed tomography. *Surg Neurol* **1984** (in press)
4. Schaltenbrand G, Wahren W. *Atlas for stereotaxy of the human brain*, 2d ed. Chicago: Year Book Medical, **1977**
5. Lunsford LD. A dedicated CT system for the stereotactic operating room. *Appl Neurophysiol* **1982**;45:374–378
6. Lunsford LD, Latchaw RE, Vries JK. Stereotactic implantation of deep brain electrodes using computed tomography. *Neurosurgery* **1983**;13:380–386
7. Lunsford LD, Leksell L, Jernberg B. Probe holder for stereotactic surgery in the CT scanner. A technical note. *Acta Neurochir* (Wien) **1983**;69:297–304
8. Fukamachi A, Ohye C, Narabayashi H. Delineation of the thalamic nuclei with a microelectrode in stereotaxic surgery for parkinsonism and cerebral palsy. *J Neurosurg* **1973**;39:214–225
9. Lillingham S. Depth recording and stimulation. *J Neurosurg* **1966**;24:382–387
10. Jasker RR, Organ LW, Hawrylyshyn PA. *The thalamus and midbrain of man.* Springfield, IL: Thomas, **1982**;505
11. Kelly PJ, Derome P, Guiot G. Thalamic spatial variability and the surgical results of lesions placed with neurophysiological control. *Surg Neurol* **1978**;9:307–315
12. Taren J, Guiot G, Derome P, Trigo J. Hazards of stereotactic thalamectomy: added safety factor in corroborating x-ray target localization with neurophysiological methods. *J Neurosurg* **1968**;29:173–182
13. Kelly PJ. Future possibilities in stereotactic neurosurgery. *Surg Neurol* **1983**;19:4–9
14. Hardy TL, Koch J, Lassiter A. Computer graphics with computerized tomography for functional neurosurgery. *Appl Neurophysiol* **1983**;46:217–226
15. Hilal SK, Maudsley AA, Silver M, Simon HE, Perman WH, Bonn J. Proton NMR imaging of the thalamic nuclei. Presented at the annual meeting of the American Society of Neuroradiology, San Francisco, June, **1983**