Stereotaxic computerized tomography with a GE 8800 scanner

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A stereotaxic system is described that uses computerized tomography scanning for target localization. This system is unique in that the stereotaxic localization may be carried out using the scanner computer without the addition of any extra software. The hardware of the system is built up around a base plate which is fastened to the scanner's patient table. The head is positioned and fixed to the base plate with aluminum bars, which are fixed to the calvaria with screws. Various stereotaxic devices may be fastened to the base plate. The system has been in clinical use for 4 months at the time of writing. Its main application has been in tumor biopsies, but it has also been used for functional operations.

KEY WORDS • stereotaxic technique • computerized tomography • tumor biopsy

TODAY computerized tomography (CT) is indispensable for the investigation of intracranial lesions. The shape, size, and internal structure of such lesions may be determined with great accuracy. The tomographic system also shows a high degree of spatial linearity, which allows accurate measurements and makes it possible to use CT for stereotaxic localization. Such systems have been described by several authors.1,8,11,12

The earlier systems for stereotaxic CT scanning all have in common the need for computer and display facilities in addition to those required for the scanner. This need for additional software and, in some cases, additional hardware has restricted stereotaxic CT scanning to a few centers. It would be advantageous to have a system that can perform stereotaxic CT scanning using only the standard equipment required for the scanner. The present article describes how a GE 8800 scanner* may be used for stereotaxic CT scanning.

Description and Technique

The stereotaxic system is built up around a base plate that is fastened to the patient table of the scanner and to the head of the patient. This ensures that the patient's head remains in a well defined position throughout the procedure. The head is positioned and fixed to the base plate with aluminum bars, either with the aid of a helmet of orthoplast or with screws fastened directly to the skull bone. In addition, various stereotaxic devices may be fastened to the base plate.

In actual practice, it proved difficult to fix the head to the base plate in a way that ensured the proper position of the head in the scanner. In order to get around this difficulty, a simulator of the scanner opening has been constructed (Fig. 1 left). The patient is placed on a bed with his head in the simulator (Fig. 1 right). The simulator has four knobs to which the aluminum base plate is fastened with a plug-in grip. Four aluminum bars (width 25 mm, thickness 4 mm) are attached by adjustable bolts onto the base plate (Fig. 2). These bars are positioned to fit closely to the head of the patient. In order to achieve a convenient position for the patient and to ensure a proper angulation of the head, the simulator opening may be moved up and down.

When the head is in the desired position, the adjustable bolts are locked. The aluminum bars have four different holes fitted for aluminum screws (Figs. 1 right and 2). The hole best suited for the fixation of the skull is selected, and the skin underlying this hole is infiltrated with local anesthetics. It is not necessary to shave the scalp, but the hair must be carefully washed with soap and 70% ethanol. With their central

*GE 8800 scanner manufactured by General Electric Corp., Medical Systems Division, 4855 Electric Avenue, Milwaukee, Wisconsin.
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Fig. 1. Left: Simulator with the square base plate attached. The base plate carries four adjustable bolts with aluminum bars. Right: The patient lying with his head in the simulator. The four aluminum bars, connected to the base plate, are screwed into the calvaria.

stainless steel cores in place, the screws are screwed into the aluminum bars and introduced into the underlying skin down to the skull bone. The central stainless steel cores are removed from the screws, and a shallow hole is drilled in the skull bone. Aluminum cores are then introduced into the screws, replacing the steel cores and extending into the shallow hole.

In order to immobilize the head of the patient in the scanner, a metal plate with four knobs similar to those of the simulator is attached to the head end of the patient table (Fig. 3). The patient lies down on the table, and the base plate which is fixed to the patient is now also attached to the metal plate of the table by the plug-in grips.

The Leksell stereotaxic system is used in our departments, and to its frame have been added four extra “feet” so as to fit into four holes in the base plate. The frame is locked to the base plate by a simple hand grip (Fig. 4 left). The frame is used both to determine the coordinates and for the stereotaxic operation itself.

The y-coordinate (height from the base plate) is determined as follows. With the Leksell frame in place, the table is positioned so that the laser beam indicating the level of the slice is exactly at the zero level of the stereotaxic frame (Fig. 4 left). The scale of the table is now brought to zero by pressing the button “Ext LM.” The stereotaxic frame is dismounted and the patient scanned. The scale indicating the level of

Fig. 2. Four aluminum bars and three sets of aluminum and steel screws are used to fix the patient to the base plate.

†The fixation system manufactured by Mediprime, Konvaljestigen 13, S-125 32 Älvsjö, Sweden.
‡Leksell stereotaxic system manufactured by A. Johnson and Co. HAB, Machinery Department for Industrial Section, Box 7714, S-103 95 Stockholm, Sweden.

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the scan will now directly show the y-coordinate of the stereotaxic frame.

In principle, this procedure should be sufficient to determine the y-coordinate. However, the scale indicating the movement of the patient table of the scanner was not constructed with the millimeter precision necessary for a stereotaxic procedure. In order to achieve a better precision, it is necessary to include some markers in the pictures that will give the exact value of the y-coordinate. The series of images are inspected to find the section that includes the target point for stereotaxic treatment (Fig. 5). The level of this scan is read off from the table scale and the control markers are applied at this level on the stereotaxic frame (Fig. 4 right). The markers are made of perspex plates with two embedded aluminum plates, each at a 45° angle to the plane of the scan. If the scan is exactly at the desired level, the images of the two structures will coincide (Fig. 6 right), and if the scan and the plane do not coincide exactly, the two structures will show a separation equal to twice the distance between the slice and the reference plane. The stereotaxic frame with the control markers is fixed to the base plate, and the patient is scanned at the chosen position. It is necessary to scan in infant mode to include the corners of the frame in the reconstructed field.

This last image will be somewhat affected by artifacts, but is of sufficient quality to ensure that the anatomy corresponds to that of the chosen plane, and that the control markers show that the proper position is chosen. The image will show the corners of the stereotaxic frame (Figs. 6 and 7).

The x- and z-coordinates (anterior-posterior and lateral in the tomographic plane) are determined with the aid of the cursor system. The command “set cursor” allows a square to be outlined in the image,
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having the same size as the inner measurements of the frame (15.4 cm) (Fig. 7 left). With the trackball, this square may be moved to fit in exactly between the corners of the stereotaxic frame. The center of this square is found by pressing the button to change from box to cross-hair, and corresponds to the zero position of the frame. This position may be saved by the command "save cursor."

The section that contains the target point but not the frame is now shown on the screen. With the command "restore cursor," the center position of the frame is transferred to this picture (Fig. 7 right). The cursor is superimposed on the target point, and with a push of the button marked "deposit," the positions of the target and the center of the frame are marked (Figs. 8 and 9). The CT coordinates are written on the screen by pressing "measure distance." The stereotaxic coordinates are obtained as the differences between the CT coordinates of the target and the CT coordinates of the center of the frame.

When the trajectory of the stereotaxic probe is in the plane of the section, it is possible to mark its path on the picture in the following way. The path of the trajectory is determined by inspection of the picture, and a point on the trajectory is marked. The path can then be traced on the image with the aid of the "measure distance" routine (Fig. 10). This procedure is of advantage when it is desirable to have multiple targets on the same line, for instance when biopsying gliomas. In that special case, it is practical to calculate the coordinates of the central target, the angle of the trajectory, and the distances between the deepest target and more superficial targets. This routine is also used when it is desirable to avoid areas that are known to be sensitive and easily injured by the passage of the stereotaxic probe. Each step in the determina-

Fig. 5. Scan of a patient with large bilateral tumors. The four aluminum plates are seen outside the skull bone.

Fig. 6. Scan of the head at the same level as in Fig. 5, showing the stereotaxic frame and indicators. Left: The bars of the frame cause artifacts in the image. The indicators are seen lateral to the head. Right: Magnification of the same scan, showing one level indicator. The white horizontal regions in the two halves of the indicator coincide, showing that the scan passed at the level that the indicator was set to indicate.
Left: A square is fitted to the corners of the frame, and the center of this square defines the origin of the coordinate system of the frame. Right: The square representing the stereotaxic frame and its center point is transferred to the scan made without the frame.

FIG. 7. Left: A square is fitted to the corners of the frame, and the center of this square defines the origin of the coordinate system of the frame. Right: The square representing the stereotaxic frame and its center point is transferred to the scan made without the frame.

The stereotaxic frame may now be reattached to the base plate, the instruments mounted, and the surgery performed in the operating theater or even in the CT room with the patient still on the scanner table.

Discussion

A stereotaxic instrument used for precise intracranial intervention has to be rigidly joined to the head. This may be done by external fixation to structures like the external meatus or the bridge of the nose, or by use of a mold around the head. A procedure using a plastic mold has been described previously. An alternative that is more accurate and also most commonly used is that in which the instrument is fixed to the calvaria with screws. One of the problems with using a stereotaxic system screwed to the head is that the metal parts will cause artifacts that may critically impair the quality of the image.

One way of avoiding this problem is to use an intermediate system that is firmly attached to the patient's head but is placed outside the CT section. The stereotaxic instrument or other devices may be attached to this intermediate system with great precision and by an easy procedure. The intermediate system, that is, the base plate, is mounted with fairly thin aluminum bars that lie close to the skull and are fastened to the calvaria with aluminum screws. Scans through the bars are only negligibly affected by artifacts. The system allows the scanning to be done without interference from the stereotaxic frame, and the accuracy in the coordinate transformation between diagnostic and therapeutic systems may be retained.

The base plate also serves to ensure that the patient is fixed to the patient table so that the distance...
between the slices is not affected by the patient's movements and that all slices in a series are parallel.

The base plate may also serve to attach different devices that aid in finding the coordinates of the stereotaxic instrument. These devices may include the instrument itself or localizing structures made of a more suitable material.

The accuracy with which the stereotaxic procedure can be performed depends on the accuracy of each step involved, on the mechanical stability of fixation, of scanner gantry and stereotaxic instrument, and on the accuracy in defining the position of reference points and target. The latter means definition of the position to a pixel point which may introduce an error of half a pixel width. With the different steps involved, the accuracy in definition of position is estimated to be about 1 mm. In the y-direction, the accuracy is determined by the widths of the sections and the distance between them. Using adjacent 5-mm slices, the accuracy is estimated to be about 3 mm.

At the time of writing, this system has been in use for 4 months. Its main application has been in tumor biopsies. For this purpose it has been found to be simple and reliable. It has also been used in functional neurosurgery, both for capsulotomies and thalamotomies. It is expected that in the near future the targets will be localized by CT scanning in most stereotaxic operations.

References

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