The stereotaxic retractor in computer-assisted stereotaxic microsurgery

Technical note

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The authors describe a cylindrical retractor that is attached to a standard stereotaxic frame. This retractor provides a route for stereotaxic procedures and exposure of and a reference structure for the computer-assisted removal of deep-seated intracranial lesions defined stereotaxically by computerized tomography and magnetic resonance imaging.

KEY WORDS • stereotaxis • computerized tomography • brain neoplasm • magnetic resonance imaging

The stereotaxic resection of deep-seated lesions has been described in our previous publications. With this procedure the tumor volume, interpolated from data gathered stereotaxically from computerized tomography (CT) and magnetic resonance (MR) imaging, is defined in three-dimensional space and vaporized with a computer-monitored, stereotaxically directed CO2 laser. Initially, in order to maintain the orientation of the laser with respect to the tumor volume, a 400-mm radius stereotaxic arc-quadrant which carried the operating microscope and laser manipulator device (Microslad) was used. However, as experience was gained in these procedures, it was found that a tubular retractor held on an inner stereotaxic arc-quadrant provided not only surgical access from the surface of the brain to the deep-seated tumor, but also a stereotaxic reference during resection of the lesions. In this report, we describe the stereotaxic retractor and its use.

Description and Use of Retractor

Description of the Instrument

The device comprises cylindrical retractors, dilators, and an arc-quadrant adaptor. Its use in the stereotaxic exposure of a deep-seated tumor is illustrated in Fig. 1. The retractors are thin-walled hollow cylinders, 140 mm in length. Two diameters, 2 and 3 cm, have proved the most useful. Indexing marks on the outer part of the shaft facilitate measurement of depth in the stereotaxic frame. The dilators fit inside the cylindrical retractors and are 1 cm longer than the retractor. The distal end is wedge-shaped to separate the walls of a linear white matter incision as the dilator is advanced. A 4-mm concentric hole through the long axis of the dilator allows equalization of pressure and prevention of a vacuum when the dilator is removed from inside the cylindrical retractor.

The retractor adaptor fits on the horizontal arc-quadrant of a commercially available stereotaxic frame.* Collett inserts, each with an internal aperture corresponding to the retractor size being used, are secured to the adaptor and grasp the retractor cylinder by means of a locking screw. This device directs the retractor cylinder perpendicular to the tangent and toward the focal point of the stereotaxic arc-quadrant.

Use of the Instrument

The stereotaxic retractor is used in the resection of deep-seated lesions. The tumor volumes are defined by CT and MR imaging and are interpolated within a three-dimensional computer image matrix. The computer slices the volume perpendicular to the surgical approach and displays the slice with reference to the configuration of the stereotaxic retractor. These stereotherapeutic techniques have proven to be effective in reducing the tumor volume and improving the surgical outcome.
FIG. 1. View of the operating room setup using the stereotaxic retractor. The arc-quadrant adaptor is mounted on the stereotaxic arc-quadrant, which directs the cylindrical retractor to maintain exposure of a deep-seated tumor. The tumor is viewed through the operating microscope and is removed with a defocused CO₂ laser beam (inset). The tumor volumes defined by computerized tomography and magnetic resonance imaging which are reconstructed within a three-dimensional computer image matrix are sliced perpendicular to the stereotaxically defined surgical viewline and displayed along with the configuration of the retractor (a circle when viewed from the surgeon's perspective) on a display monitor in the operating room.

taxic procedures are performed in three stages: data acquisition, treatment planning, and interactive surgery. First, for data base acquisition and for surgery, a stereotaxic head frame compatible with CT and MR imaging is applied while the patient is under local anesthesia. The head frame is attached to the patient's skull by means of four flanged carbon-fiber pins which are inserted through the outer table of the skull into the diploe. Detachable micrometers are used to record the relationship of the fixation pins to the vertical support elements of the head frame. By this means, the head frame may be removed and reapplied in precisely the same position for subsequent data acquisition and surgical procedures.

Data Base Acquisition

Stereotaxic CT Scanning. A CT table adaptation plate is attached to the scanning table of the General Electric 8800 or 9800 CT scanner. This is similar to the receiving yoke on the base unit of the stereotaxic head holder. Reference marks on the head frame are aligned on the CT table adaptation plate as they are to the receiving yoke of the stereotaxic base unit during the surgical procedure.

A localization system is attached to the base ring of the head frame; this system consists of carbon-fiber rods arranged in the shape of an N on either side of the head and anteriorly. This creates nine reference marks on each CT slice from which the height and inclination of the slice above the base ring may be determined as described previously.²

Stereotaxic Magnetic Resonance Imaging. Stereotaxic MR examinations are performed on a Picker 0.15-tesla resistive unit. An MR imaging-compatible base ring constructed of molybdenum disulfide is attached to a vertical support and fixation system identical to the CT-compatible head frame described above. A transverse localization system resembles that designed for CT. It consists of nine capillary tubes filled with CuSO₄ solution. These create nine reference marks on each MR image.

Tumor Volume Reconstruction

The archived computer data tapes from stereotaxic CT and MR examinations are input into the operating room computer system. The reference marks on each CT slice and MR image are identified automatically, and the position of each slice is established in stereotaxic space within a computer image matrix as described previously.

The surgeon digitizes the boundary of the target volume.
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lesion on contiguous CT slices and MR images using the display unit's cursor and trackball subsystem and deposit key. The computer suspends each digitized boundary within the three-dimensional image matrix, interpolates intermediate slices at 1-mm intervals, then fills in each digitized and interpolated slice with 1-mm cubic voxels, thus creating a solid volume in stereotaxic space. In addition, a reference target point located within the lesion on one of the CT slices or MR images is digitized. The interpolated volumes defined by CT and MR images will be constructed about this point. The computer calculates the mechanical adjustments that will bring this point into the focal point of the stereotaxic arc-quadrant frame. The CT- and MR image-defined volumes may then be sliced perpendicular to any specified viewline, expressed in arc (angle from the vertical plane) and collar (angle from the horizontal plane) settings on the stereotaxic instrument. In addition, the volume, target point calculations, and angle that defines the viewline can be reformatted by the computer for any patient rotation (0° = supine; 90° = right shoulder down, lateral decubitus; 180° = prone, etc.) in order to provide a comfortable surgical working situation for the surgeon.

Surgical Procedures

The stereotaxic retractor and arc adapter can be used on a standard, commercially available stereotaxic instrument and on a custom-made arc-quadrant stereotaxic frame developed at our institution. In principle, both of these systems consist of a fixed arc-quadrant and three-dimensional slide system with which the patient's head is moved in three-dimensional space to place a defined intracranial target point into the focal point of the fixed arc-quadrant.

The target point within the tumor volume is mechanically positioned into the focal point of the stereotaxic arc-quadrant by moving the three-dimensional slide to duplicate the x, y, and z coordinates which have been calculated by the computer. Any instrument directed perpendicular to a tangent of the arc-quadrant and inserted to a depth equal to the radius of the arc-quadrant will automatically arrive at its center. No phantom system is necessary. Entry-point and approach trajectory angles are expressed in arc (angle from the vertical plane) and collar (angle from the horizontal plane) settings. Angular settings on the instrument are determined and set on the arc-quadrant. A linear scalp incision is made, a 1½-in. circular cranial trephination is performed, and the dura is opened in a cruciate fashion. The retractor cylinder is placed between the retracted edge of a linear incision made in the crown of a gyrus or between gently retracted gyral banks of a deep sulcus opened by microsurgical technique. The dilator is inserted and advanced until it rests in the depths of the incision (Fig. 2A). The retractor cylinder is advanced 5 mm over the dilator, then the dilator is removed (Fig. 2B). Following this, the operating microscope is used to view the depths of the incision through the retractor. The subcortical linear incision is extended 5 to 10 mm deeper by means of a focused CO₂ laser beam (Fig. 2C). The incision should be made parallel to the known direction of the major white matter fibers in the area. The dilator is then reinserted and the cylindrical retractor is advanced 5 mm further (Fig. 2D and E). The dilator is removed and the incision is deepened further (Fig. 2F). Thus, a long subcortical incision from the surface of the brain to the tumor is made in small steps which consist of deepening the incision with the CO₂ laser and spreading the incision with the dilator over which the retractor is advanced and secured. Bleeding is controlled utilizing an extra-long bipolar forceps. At the outer border of the tumor, the incision is undercut medially and laterally, reflecting

† Todd Wells stereotaxic instrument manufactured by Trent Wells, Inc., Southgate, California.

‡ Kelly stereotaxic bipolar forceps manufactured by Radionics, Inc., Burlington, Massachusetts.
FIG. 3. The retractor position (circle) is seen displayed against the tumor boundaries as defined by computerized tomography and magnetic resonance images.

FIG. 4. Preoperative (left) and 2-day postoperative (right) contrast-enhanced computerized tomography scans in a patient with a thalamic astrocytoma. Note the surgical pathway through the anterior limb of the internal capsule. This patient had no deficit postoperatively.

The retractor maintains the surgical exposure and provides a convenient reference for the depth of the stereotaxic procedure as follows. The radius of the arc-quadrant and the length of the retractor are known. The distance of the end of the retractor from the focal point can be determined using the following equation: 

\[ D = (L - R) - M \]

where \( D \) is the depth of the retractor with respect to the stereotaxic zero point, \( L \) is the length of the retractor (140 mm), \( R \) is the radius of the stereotaxic arc-quadrant (135 mm), and \( M \) is the measured distance from the outer rim of the stereotaxic arc-quadrant to the end of the retractor.

The lesion has been reconstructed as a three-dimensional volume from interpolated stereotaxic CT- and MR-digitized boundaries within a computer image matrix. The volume may then be displayed as a series of slices cut perpendicular to a specified surgical viewline which corresponds to the retractor trajectory. This trajectory is expressed as arc and collar settings on the stereotaxic arc-quadrant. Given this information, the operating computer system can display the configuration of the cylindrical retractor as viewed by the surgeon (Fig. 3, circle) in reference to the reformatted CT- and/or MR image-displayed tumor outlines on a calibrated millimeter reference grid. The configuration of the tumor reconstructed from the imaging data can then be related to the image of the retractor on the computer display screen and in the operative field. This will orient the surgeon as regards the edges of the tumor with respect to the retractor.

The retractor can be repositioned so that tumors larger than the retractor opening can be removed. In order to do this, the displayed tumor slice is translated on the computer display screen in order to place a new area under the retractor. The computer then calculates new stereotaxic frame settings that will duplicate in the operative field the situation displayed on the screen. The patient's head is then translated in the stereotaxic frame in order to place the new calculated target point into the center of the stereotaxic arc-quadrant. During this movement, the proximal end of the retractor is also moved by sliding the adaptor on the stereotaxic arc-quadrant and changing the collar angle in order to have the shaft of the retractor centered within the cranial trephination. New arc and collar settings are read off the stereotaxic arc-quadrant and input to the computer which then reformats the volume with respect to the new retractor trajectory.

Clinical Experience

The stereotaxic retractor has been employed in the resection of 123 deep-seated intracranial lesions and 21 stereotaxic amygdalohippocampectomies between August, 1984, and August, 1986. There have been no hemorrhagic or intracranial hypertensive complications related to the use of the stereotaxic retractor. No postoperative neurological deficits related to the surgical approach or retractor system were noted when the surgery of mass lesions employed trajectories that traversed nonessential brain tissue in a direction parallel to white matter fibers (Fig. 4). However, incisions into and separation of neurologically important tracts by this method can result in a neurological deficit.
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FIG. 5. Left: Lateral stereotaxic teleradiograph obtained during a left stereotaxic amygdalohippocampectomy. The 2-cm diameter stereotaxic retractor is advanced through the temporal lobe directed from a lateral posterior entry point to an anterior medial temporal target volume (from right to left in the picture). Right: Visual field examinations in this patient performed 1 week (upper) and 3 months (lower) after surgery. Note that the superior quadrantanopsia initially noted postoperatively has improved to a partial visual field defect. No postoperative receptive or expressive speech deficits were noted at any time in the postoperative period.

example, all of the patients who underwent stereotaxic amygdalohippocampectomy using a posterior lateral approach and an inferior posterior temporal occipital entry point had a persistent partial superior quadrantanopsia on postoperative neurological examination (Fig. 5). This was presumably due to trauma to geniculo-calcarine fibers within the sublenticular portion of the internal capsule.8

Discussion

The stereotaxic retractor system described in this report is convenient for the approach to and exposure of deep-seated lesions. In addition, the retractor itself provides a fixed reference structure with a known position in stereotaxic space. Thus, the computer can relate and display slices from the tumor volume defined by CT and MR imaging with respect to the position of the distal end of the retractor.

The CO2 laser is convenient for deepening the subcortical incision through the retractor opening and for removing some lesions. Extra-long dissecting instruments, forceps, and scissors must be custom-made at present; however, some practice in microsurgical technique utilizing this extra-long working length is required. With this device and method, controlled gross total resections of large deep-seated tumors can be performed through a 2-cm diameter retractor.

It is our feeling that a cylindrical retractor does less damage than standard bladed retractors, considering that retraction of both sides of a deep incision with flat retractor blades makes a square opening and the edges of the blades may injure brain tissue. However, it is important to be gentle in the insertion of the dilator which precedes advancement of the retractor in order to reduce damage to incised cortical tissue and white matter tracts as they are pushed aside by the dilator. White matter fibers can be damaged by the stereotaxic retractor system; we have noted visual field defects following posterior inferior temporal approaches to medial posterior temporal targets exposed by this method. When using this system, it is best to select a route to a deep-seated tumor which traverses nonessential white matter pathways.

References


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