Computerized three-dimensional stereotaxic removal of small central nervous system lesions in patients

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The authors describe the results of their recently reported computer-based stereotaxic surgical technique for the identification, enhancement, three-dimensional reconstruction, localization, and removal of small central nervous system lesions. This technique has been applied to patients with various types of central nervous system pathology, and representative cases are reported.

Key Words · stereotaxis · Shelden tumorscope · three-dimensional reconstruction · computerized surgery · brain tumor · intracerebral hematoma · arteriovenous malformation

The advent of improved software and hardware in computerized tomographic (CT) analysis of the brain has enabled neurosurgeons to identify lesions at an earlier stage than was previously possible. Based upon this technology, we have recently reported a refined technique to identify and remove small central nervous system (CNS) lesions with a newly designed tumorscope. In this paper, we report some representative cases of central nervous system pathology recently removed by the use of this technique.

Surgical Technique

All patients were selected for this surgery on the basis of the small size of the CT scan defect, and the proximity of the lesion to important central nervous system areas. Routine CT scans were performed before patient selection on a GE 8800 Scanner* with 5-mm cuts through the area in question. Information from each scan was transferred from the GE scanner tape to a floppy disc on a PDP 11/45 computer at the California Institute of Technology for further inspection. Scanning enhancement techniques by subtraction, color coding, magnification, and other algorithm manipulations have been described previously. All lesions were three-dimensionally reconstructed before stereotaxic surgery to better define the exact volume, size, and shape of the abnormality.

On the day before surgery, the patients were admitted to the Huntington Memorial Hospital or the UCLA Medical Center Hospital for routine preoperative workup. On the morning of surgery, the patients were taken to the CT scanning suite at the Huntington Memorial Hospital in Pasadena, California, where the modified stereotaxic ring was placed on the head after routine clipping of the hair, scalp sterilization, and instillation of local anesthesia. The patients were placed on the CT scan table and secured to the base mounting system. A repeat scan through the lesion area and the ring was carried out and transferred to magnetic tape. This tape was then taken to the computers at the California Institute of Technology for xyz-coordinate calculation while the patients were removed from the base-mounting system and transferred to the operating room.

The patients were there intubated, prepared for operation, and draped, and the ring was remounted to the operating room fixation mount (Fig. 1 left). After

*General Electric CT/T 8800 scanner manufactured by General Electric, Medical Systems Division, Milwaukee, Wisconsin.
coordinates for the xy- and z-axes were obtained, they were set on the phantom ring of the stereotaxic apparatus, the halo was placed on the phantom with the micromanipulator and "tulip petals" in place, and the appropriate angle selected for entry. The micromanipulator was then advanced to the depth of the lesion, the readings from the micromanipulator and the halo-stabilizing bar noted, and the halo transferred to the patient ring (Fig. 1 right). The scalp was marked at the appropriate place, and the halo removed from the patient ring. Routine scalp incisions were made, and a small trephination placed coincident with the appropriate angle of entry. After the dura had been opened and the pia incised transversely over a length of approximately 4 mm, the halo was reapplied to the patient ring and the series of dilators used to approach the appropriate z-axis depth of the lesion. Finally, the tulip was mounted on the micromanipulator, run into the brain, and opened to expose the lesion at the appropriate coordinate settings.

The actual surgical removal of the lesions was carried out with a series of specially designed biopsy forceps, small dissectors, and a rotosucker-dissector designed specifically for use within the tulip. Lesion removal was greatly enhanced by preoperative, threedimensional reconstruction of the lesion in question, and the ability to operate with binocular vision afforded by the optical system designed for use with the tulip. After the lesion had been removed, routine neurosurgical closure was performed. The patient and the ring were removed from the base-mounting system, the ring removed from the patient's head, and the patient sent to the recovery room for routine postoperative care.

Case Reports

Case 1: Metastatic Tumor

This middle-aged woman was admitted to the Huntington Memorial Hospital in Pasadena in October, 1979, with a 3-month history of focal left-sided seizures. The patient had had a CT scan elsewhere, where a small, right-sided, ring-type lesion was seen in the motor cortex; the lesion enhanced on administration of contrast medium. She subsequently underwent craniotomy at another institution, but the lesion in question was not found.

Neurological examination at the time of admission revealed a left hemiparesis. Routine preoperative chest films revealed a questionable small mass in the left superior sulcus. Preoperatively, the patient had a complete CT series on the GE 8800 scanner, with 5-
mm cuts through the small right-sided enhancing lesion. This was three-dimensionally reconstructed for use at surgery (Fig. 2). On the day of surgery, the patient had a repeat scan with the head ring attached for stereotaxic coordination to the lesion. She then underwent computer-based stereotaxic surgery with removal of a small metastatic adenocarcinoma of the lung. Postoperatively, the patient has shown continued improvement of her left hemiparesis. She has subsequently undergone what is considered to be a complete removal of the lung adenocarcinoma.

Case 2: Astrocytoma

This 60-year-old man was referred to the Huntington Memorial Hospital following a recent hospitalization, during which a routine CT scan showed a small lesion in the right posterior frontal region (against the falx) which was initially interpreted as a meningioma. He was essentially asymptomatic but, during the months since the original CT scan, had developed marked weakness in flexion of the left hip.

The patient was admitted to the Huntington Memorial Hospital in October, 1979, and had a repeat scan through the area in question on the day of admission. The scan was consistent with a larger right posterior frontal enhancing lesion along the falx, and was three-dimensionally reconstructed for preoperative evaluation (Fig. 3). The following day, the patient underwent a repeat CT scan with the head ring attached, followed by stereotaxic removal. The surgical findings were consistent with a Grade 2 astrocytoma. The patient has since been steadily improving for approximately 6 months.

Case 3: Arteriovenous Malformation

This 40-year-old man was referred to the Huntington Memorial Hospital with a 3-month history of subjective numbness in the left hand. He had had a routine CT scan performed elsewhere that showed a questionable small right parietal enhancing lesion. He was referred to us for further evaluation and treatment, and was subsequently admitted to the Huntington Memorial Hospital in January, 1980.

A routine CT scan with 5-mm cuts through the right parietal area in question revealed a very small enhancing lesion. Cerebral angiography was normal. The CT scan was further evaluated by magnification, color coding, and three-dimensional reconstruction (Fig. 4). The following day, the patient underwent a routine repeat CT scan with the head ring attached for localization of the lesion. Stereotaxic surgery revealed a very tiny occult arteriovenous malformation (AVM), approximately 4 cu mm in size, with some surrounding area of hemorrhage, which was completely removed. The patient’s postoperative course was very innocuous (as indeed it was in all these cases), in that he was released and married within 1 week of the surgery.

Case 4: Glioblastoma

This 42-year-old man had been in good health until approximately 3 weeks before he presented to his physician with a chief complaint of some headaches and inability to control his micturition. Routine CT scan revealed a deep frontal enhancing lesion, and he was subsequently referred to the UCLA School of
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Case 5: Multiple Metastases

This 40-year-old woman was referred to the UCLA Medical Center with a known carcinoma of the lung. Routine CT scans had revealed two metastatic lesions, one large tumor in the left occipital area and a very small right parietal enhancing defect (Fig. 6). Her neurological examination was unremarkable.

The patient underwent two computer-based stereotaxic operations for these lesions. At the first, in February, 1980, she underwent a CT scan at the Huntington Memorial Hospital with the head ring attached for scalp localization of the more posterior lesion. The tumor was removed in conventional fashion at the UCLA Hospital. After a benign postoperative course, she had a repeat CT scan, and the ring was reapplied for stereotaxic localization of the more anterior right parietal lesion. This tumor was then removed with the techniques described above, and the patient’s postoperative course has again been benign.

Case 6: Intracerebral Hemorrhage

This 70-year-old man was admitted to the Huntington Memorial Hospital in February, 1980, with a significant past history of multiple myocardial infarctions. He had subsequently been placed on anticoagulants. The patient had had a stroke in the remote past, leaving him with a residual left upper extremity deficit.

During the night before admission, he had the sudden onset of headache, confusion, and right upper extremity weakness, followed by a personality change. Routine CT scan on the day of admission revealed a small left frontal intracerebral hematoma which was subsequently three-dimensionally reconstructed for...
localization at surgery (Fig. 7). The patient later underwent stereotaxic removal of the hematoma after rescanning with the ring in place. The patient's postoperative course was one of continued improvement in both motor strength and personality. He was discharged after returning to his preoperative neurological state.

Discussion

This newly designed method for computer-based stereotaxic surgery in humans is described, with examples of its use in the treatment of astrocytomas, Grades 2 and 3, metastatic tumors, arteriovenous malformations, and intracerebral hematomas. Multiple computer algorithms developed at the California Institute of Technology and described previously have allowed enhancement of regions of interest by magnification, filtering, color coding, and three-dimensional reconstruction based on routine CT scans.\(^1\)\(^2\) The stereotaxic approach is calculated by the computer from the raw CT data. These stereotaxic coordinates are then fed into the head fixation system modified from the Riechert-Mundinger stereotaxic system.\(^3\) Such small lesions can then be removed with the "Shelden tumorscope" and other microsurgical apparatus described previously, under direct binocular vision via a small burr hole or trephination, causing minimal damage to surrounding brain.\(^1\)\(^2\) The stereotaxic frame accurately defines all areas of the cranium in three-dimensional coordinates, and its combination with the three-dimensional coordinates that have been located by additional computer processing of the CT digital data enables the site of any small (or large) CNS lesion to be accurately approached by the stereotaxic guide-micromanipulator assembly. This technology and its application as described has allowed for a complete removal of very small tumors. The technique is also curative in terms of dealing with small AVM's, intracerebral hematomas, and perhaps metastatic tumors.

The ease of this surgery, the extreme accuracy of the technique, and its benign postoperative course have been impressive.

\(^1\)Riechert-Mundinger stereotaxic unit manufactured by F. L. Fischer GHMB, Freiburg 1/BR., West Germany.