Computer-Assisted Stereotactic Neuronavigation for Intracranial Mass Lesions: Preliminary Clinical Experiences in 63 Cases

İntrakranial Kitlelerde Frameles Stereotaksik Nöronavigasyon: 63 Olgudaki Öncül Klinik Deneyimler

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Abstract: Objective: Computer-assisted stereotactic frameless navigation techniques are used in many centers for intracranial neurosurgical procedures. In this study, we assessed the accuracy and the clinical usefulness of a frameless system based on the optical digitizer in a variety of intracranial procedures.

Method: The stereotactic neuronavigation system was used in 67 cases of different brain pathological conditions. The neuronavigation system is based on passive reflections of infrared flashes. Universal adapters with reflective markers for different surgical instruments such as surgical aspirator, bipolar forceps and dissectors were used. In 63 cases the system proved to be very helpful in planning and guiding surgery for intracranial mass lesion with a target localizing accuracy of 1,7±1.3 mm (mean ± standard deviation).

Results: There were no complications attributable to inaccurate localization from the neuronavigation system. Additional set up time was necessary to calibrate and register the system, and this represented e mean of 14±5 minutes. The average size of the lesion in these patients was 3.13 cm in greast diameter (range 1.1 – 7.8 cm). Most lesions were supratentorial (77%, 48/63) and subcortical in location (64%, 40/63). In four cases, neuronavigation could not be performed because of system failure or mishandling.

Özet: *Amaç:* Frameless stereotaksik nöronavigasyon sistemleri bazı merkezlerde intrakranial kitlelerin cerrahi tedavisinde kullanılmaktadır. Bu çalışmada çeşitli intrakranial kitlelerde optik digitizer esasa dayalı bir frameless nöronavigasyon sisteminin doğruluğu ve klinik kullanımdaki yararlılığını değerlendirdik.

Yöntem: Sistem 67 olguda kullanılırken, 63 olguda başarılı bir şekilde uygulanmış fakat 4 olguda sistem hatası veya belirleyicilerin hareket etmesine bağlı olarak uygulanamamıştır. Sistemin kalibrasyon ve registirasyon süresi ortalama 14 dakika idi. Lezyonların çoğu supratentoryal (48/63, % 76) ve subkortikal (40/63, % 63) lokalizasyondaydı.

Sonuç: Nöronavigasyon sistemi cerraha leyonun lokalizasyon ve sınırlarının belirlenmesinde yardımcı olarak, devamlı 3 boyutlu interaktif görüntü sağlamaktadır. Bu nedenle bu sistem intrakranial kitlelerde cerrahinin planlanması ve seyrinde oldukça faydalıdır.

Conclusion: The stereotactic neuronavigation system has proven to be a helpful tool for surgical treatment of different brain pathological conditions. Computer-Assisted Stereotactic Neuronavigation is a technology, which provides continuous, interactive images, three-dimensional information for localization and surgical trajectory to the surgeon and is usefulness in planning and guiding surgery of intracranial mass lesions.

Key words: Cerebral lesion, stereotactic neuronavigation

Anahtar kelimeler: Serebral lezyon, stereotaksik nöronavigasyon

INTRODUCTION

Microsurgical technique combined with precise localization of the lesion minimizes the invasiveness of neurosurgical procedures. Precise targeting of small brain lesions (Figure 1), even in subcortical (Figure 2) and deeply located brain areas, is still a challenge to neurosurgeons. The accuracy of computerized tomography (CT) and magnetic resonance (MR) image guidance to an intracranial lesion is constrained by the static nature of the preoperative image data. The use of frameless stereotactic systems for intraoperative image guidance has evolved considerably over the last decade (3, 4, 6, 8, 9, 10, 12). Intraoperative image guidance using the Computer-Assisted Stereotactic Neuronavigation system for surgery for intracranial mass lesions has become routine at our institution since from June 2000. In this article, we present the technical application of and our preliminary experience with the neuronavigation system (BrainLAB Vector Vision2, Munich, Germany) for 63 patients harbouring different brain pathological conditions.

PATIENTS AND METHODS

Fifty-seven patients with intracranial lesions underwent surgery throughout different transcranial approaches between June 2000 and November 2000 using the computer-assisted neuronavigation system. In the beginning, we experienced function errors in four patients because of the system was failure or mishandling. In 63 cases, the system worked adequately. In 63 cases, the neuronavigation system was used for microsurgical treatment of different brain pathological conditions (Table 1).

For computer-assisted stereotactic neuronavigation, each of the 67 patients underwent a preoperative CT or MR scans associated with contrast enhancement with fiducial markers. Five to six markers were affixed to bony surface of the cranium such as the glabella, infront of the tragus, mastoid tip and near of the intracranial lesions. Three-millimetres axial slices were obtained on the CT or MR scans. These data were then transferred to the computer workstation in the navigation planning room via ethernet or MOD disc for CT and MR, respectively.

The Brain LAB VectorVision uses Windows NT 3.51–based software. The system computer reformatted the axial images into coronal and sagittal views and three-dimensional images. The three-planar images can be viewed in interactive in each of the three planes and three-dimensional images. On the three-dimensional images, the lesion, the eloquent areas, ventricles or brain stem can be assigned different colors according to landmarks of MR images. Surgical planning was recorded on the zip disc in order to conduct to the operating room.

Table 1: Histological diagnosis and surgical removal for 63 patients

Diagnosis	Number of Cases	Surgery	
		Total	Subtotal
Gliomas	17	8	9
Meningiomas	8	6	2
Metastatic tumors	7	6	1
Craniopharyngiomas	2	1	1
Hypophyseal tumors	8	7	1
PNET	4	3	1
PCAT	3	3	
Skull base tumors	4	3	1
Vascular malformation	7	6	1
Miscellaneous	3	3	
TOTAL	63	46	17

PNET: Primitive neuroectodermal tumors; PCAT: Pontocerebellar angle tumors

The Mayfield head holder is applied to the cranium and is attached to the operating table (OMI, Inc., Cincinnati, OH). After the anesthesized patient positioning, because of the most causes of the failure of the navigation were the disconnection or movement of the reference arc, a rigid mechanical connection was established between the head holder and the reference arc. The reference arc locked to the Mayfield headrest array to establish a constant relation between this reference array and the fiducial while flexibility for subtle head movements during the procedure is maintained. Then, the patient to image registration was performed using nonsterile handheld pointer kept on each one of the adhesive markers until the registration accuracy was within 3 mm. After the registration was completed, nonsterile reference arc was replaced with sterile ones. Then, the scalp incision was planned according to the images of the lesion on the screen and the scalp was prepared using sterile technique. To ensure intraoperative accuracy, we verified the system's localization against the nasion, tragus, and zygomatic arcus before beginning the incision. By defining the borders of the lesions, the most minimal craniotomy can be performed. The tips of the instruments can be virtually prolonged, and thus the depth of the lesion, as well as the direction of the approach, can be displayed on the computer screen. The intraoperative accuracy is confirmed using skin fiducials, the bone surface, small burrholes drilled into the cranium, and tumor margin before removal.

RESULTS

The system could not be used in four cases because of the system was failure or mishandling. These failures occurred in the beginning of the study. We spent an additional time approximately 14±5 minutes to establish the system. The locations were supratentorial in 48 cases, infratentorial in 15 cases (Table 2). The discrepancy between the tumor margin in the operating field and the margin demonstrated on the computer screen is measured for accuracy (before tumor removal). The duration of surgery ranged from 70 minutes to 360 minutes and was not affected by the navigation procedure. The overall intraoperative accuracy, including the mechanical precision of the system, was a mean of 1,7±1.3 mm. In most cases, the size of craniotomy could be kept small (2-5 cm in diameter). We never performed an exploration with negative results. In 46 cases, the lesions were removed completely, as confirmed by postoperative CT or MRI performed within 24 hours (Figure 1, 2, 3). In 17 cases, only subtotal removal was achieved because the tumors had infiltrated eloquent regions or the brain stem (Table 1).

Table 2: Location of the lesions

Location	Number of Cases
Supratentorial	48
Cortical	9
Subcortical	33
Deep-seated	6
Infratentorial	15
Cortical	3
Subcortical	7
Brain stem	5
TOTAL	63

DISCUSSION

Stereotactic surgery has been used for decades. In 1991, a frameless, armless, navigational system was described by Kato et al (7). Ryan et al (11) described a frameless stereotactic with interactive tracking of patient head movement.

The VectorVision neuronavigation system from BrainLAB is an advanced image guided surgery system (3, 6, 9). Due to its unique wireless passive marker technology it enables real freehand guidance and integrates easily all kinds of instruments. Frameless navigation systems bring the surgeon a step closer to rendering surgery less invasive. Incisions and craniotomies are smaller due to the system's more targeted approach. Easy and safe intraoperative localization of deep-seated lesions as well as differentiation of normal and lesion tissue are supported. Combined, these features reduce the risk of complications and save time and cost. Easy, on-site calibration minimises downtime and the need for outside service.

In this neuronavigation system, intraoperative data for localisation are acquired as two infrared cameras activate and receive the signal emitted from reflective markers placed on a reference arc array attached to a Mayfield clamp, which is fixed to the patient's head. Various reflective marker arrays were applied to surgical instruments so that they could be used as active pointers throughout the procedure. An advantage of the passive marker technology is that various kinds of instruments can be equipped with universal adapters with three reflective markers. Thus, any instrument can be used as a navigation tool merely by simple calibration of its geometry. This saves cost and frees the surgeon from the restriction of using special pointers. In this way, continuous data are

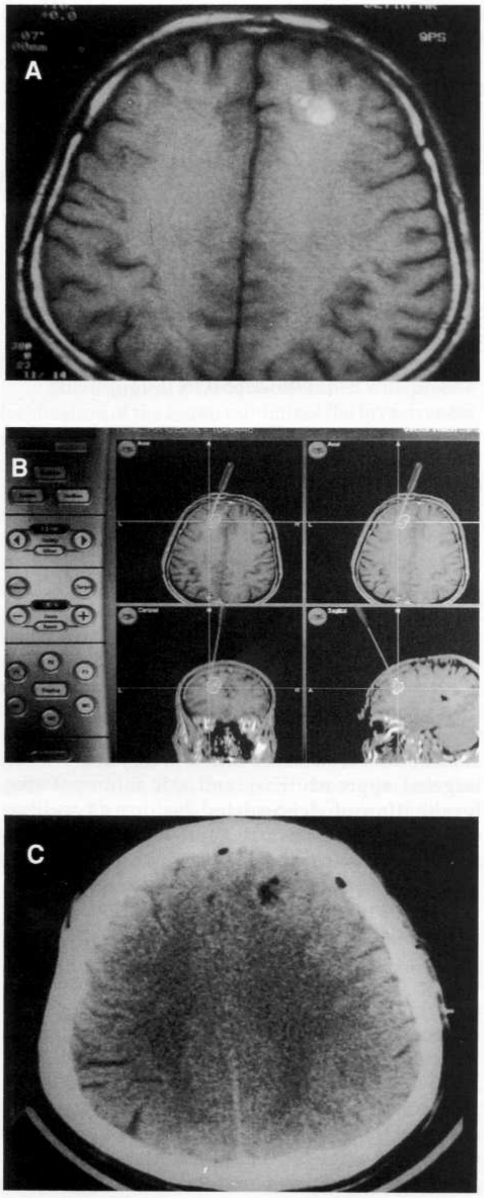

Figure 1 a: Axial MRI brain image after contrast medium administratiom shows a homogeneous enhancing left frontal lesion. b: Intraoperative neuronavigation picture. c: Postoperative axial image confirms gross total resection.

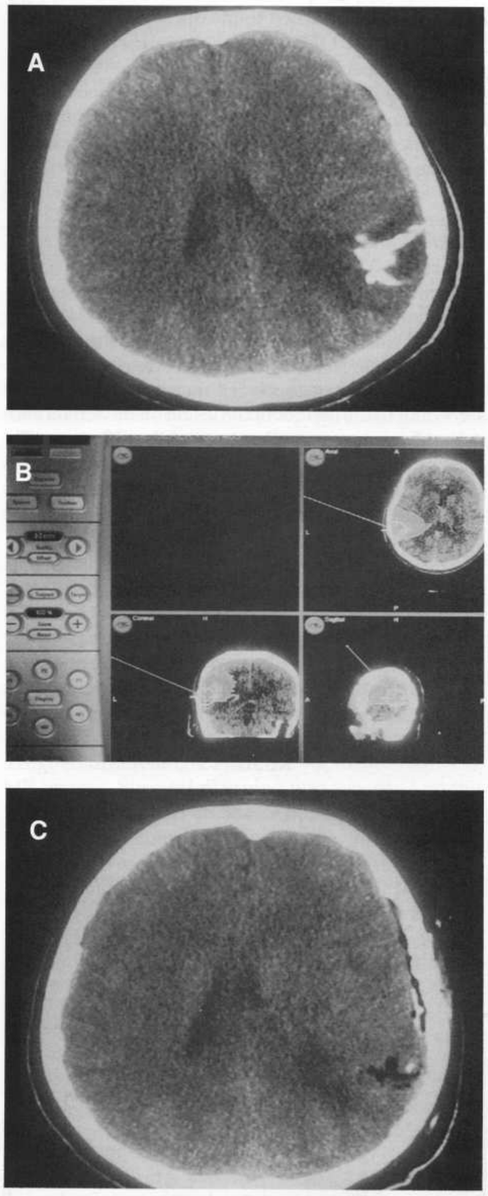

Figure 2 a: Axial CT scan showing a temporooccipital lesion consistent with calcification. b: Intraoperative navigation picture showing the margin of the lesion and its calcify component. c: Axial CT scan postoperatively demonstrates the resection of the lesion with gross totally.

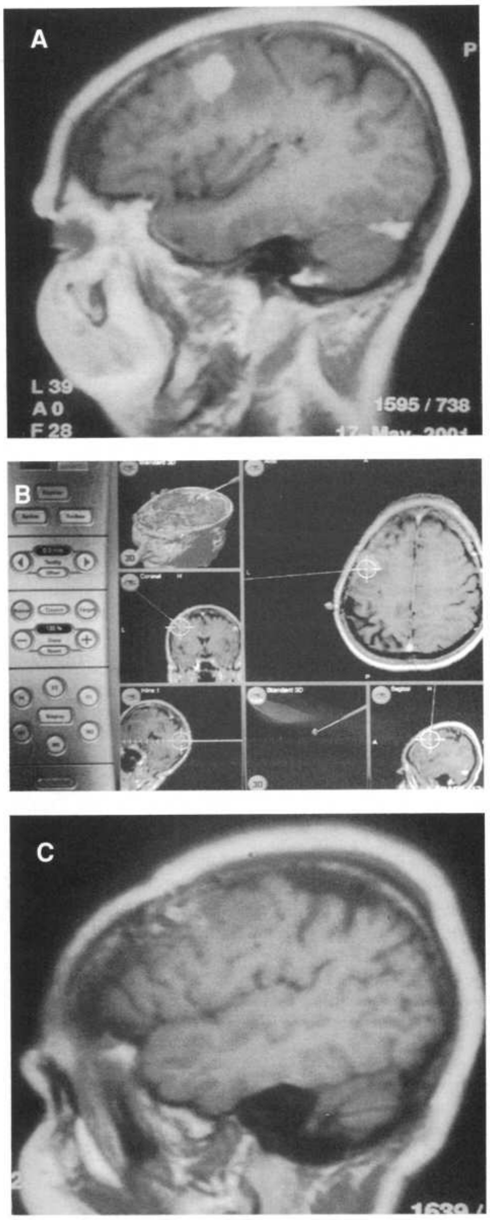

Figure 3 a: Sagittal MRI brain image after contrast medium administration shows a homogeneous enhancing left frontoparietal lesion. b: The intraoperative navigation picture showing the margin of the lesion. c: The sagittal postoperative MRI image confirms gross totally resection.

update into the system and are available to the surgeon in interactive. Recent years, stereotactic neuronavigation can be combined with operating microscope. We have used microscobic stereotactic neuronavigation for last four months.

Our indications for using the neuronavigation system were three fold: first is to plan the craniotomy and therefore minimize the required surgical exposure; second is to locate deep seated subcortical lesions; and third is to aid in the extent of resection.

The computer-assisted stereotactic neuronavigation system was particularly useful in planning the craniotomy of dural-based lesions such as meningiomas. Definition of the margins of tumor attachment to the dura may optimise the shape of craniotomies, thereby aiding complete resection and potentially lowering the risk of recurrence. Neuronavigation system can provide visualization of the relationship of tumor to venous anatomy, which may reduce the risk of devastating infarction. Cortical surface anatomy can also be assessed, aiding to estimate risk to functionally eloquent areas (1). Even a very simple removal of a convexity meningioma can be planned to minimize the scalp and bone flap required to completely remove it. Important adjacent structures, such as dural sinus and major arteries, can be identified, marked, and spared.

Computer-assisted stereotactic neuronavigation system was also helpful in locating small, subcortical or deep-seated lesions such as metastases, primary intrinsic brain tumors, brain abscess, and cavernous angiomas (5, 6). This system was useful in establishing tumors/lesions boundaries before resection and in determining the extent resection. Within the depth of the lesions, neuronavigation is extremely useful. However, it must be tempered by experience and the constant concern that structures may shift. A well-known problem of all image-guided procedures is the shifting during surgery of cerebral structures relative to the preoperative imaging data set (2). In our study, we could not detect a significant brain distortion unless the excessive CSF removal or tumor resection is performed. The ultrasound integration, the system is most attractive for routine use. In addition, to minimize error resulting from brain shift, we adopted several measures that deviate from classic tumor resection technique. First, neither mannitol nor diversion of cerebrospinal fluid was used routinely. Patients undergoing craniotomy were hyperventilated throughout the surgical procedures. If the brain was tense, a small bolus mannitol (0.3-0.5 g/kg) was administered intravenously before the dura was opened. Second, intrinsic tumors were removed en bloc to minimize the amount of tissue shift that occurs after typical debulking resection. Finally, extreme positioning of the head such as full lateral, full flexion-extension was avoided to reduce shift and facilitate the interpretation of the real-time feedback on the computer images.

Surgery of the skull base is marked by a variety of risked vascular and neural structured in confined space. Because of the destructive nature of lesions affecting the skull base, surgical and anatomical landmarks may be lacking thus increasing the risk of intraoperative complications. Neuronavigation system represents an important supplementary aid of a more precise intraoperative orientation based on computer-assist imaging techniques. In addition, the system error due to brain shift was not noticed because of the skull base is a constant anatomical structure (8).

Transsphenoidal surgery has dramatically reduced the morbidity associated with the surgical treatment of sellar lesions. Major complications can occur and almost invariably result from errant approaches. In repeat operation, midline anatomic landmark are absent or disrupted. Because of the intraoperative images taken with C-arm fluoroscopy are on sagittal plane, one should not rely upon intraoperative fluoroscopy to confirm on the midline. Majority reasons of the complications related to transsphenoidal surgery are not to be in midline (3). Computer-assisted stereotactic neuronavigation is a technology that provides continuous, three-dimensional information for location and surgical trajectory to the surgeon and can be applied to transsphenoidal surgery to increase safety with minimal additional time requirement. Additionally, fluoroscopy that can be hazardous for both surgeon and patient was not required when neuronavigation system was used.

CONCLUSION

The computer-assisted neuronavigation system has proven to be a helpful tool for surgical treatment of different brain pathological conditions. This frameless navigation technology can provide useful information to assist craniotomy for lesions located cortical, and subcortical areas. Definition of the limits of tumor may optimise the position, size, and shape of craniotomies, thereby aiding complete resection and potentially lowering the risk of brain retraction. Cortical surface anatomy can also be assessed, helping to estimate risk to functionally eloquent areas. The additional time required for preparation is approximately 14 minutes; on the other hand, the length of surgery can be decreased with smaller craniotomies and more direct approach.

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