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Computer-Assisted Neurosurgical Navigational System for Transsphenoidal Surgery
—Technical Note—

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Abstract

Transsphenoidal surgery carries the risk of carotid artery injury even for very experienced neurosurgeons. The computer-assisted neurosurgical (CANS) navigational system was used to obtain more precise guidance, based on the axial and coronal images during the transsphenoidal approach for nine pituitary adenomas. The CANS navigator consists of a three-dimensional digitizer, a computer, and a graphic unit, which utilizes electromagnetic coupling technology to detect the spatial position of a suction tube attached to a magnetic sensor. Preoperatively, the magnetic resonance images are transferred and stored in the computer and the tip of the suction tube is shown on a real-time basis superimposed on the preoperative images. The CANS navigation system correctly displayed the surgical orientation and provided localization in all nine patients. No intraoperative complications were associated with the use of this system. However, outflow of cerebrospinal fluid during tumor removal may affect the accuracy, so the position of the probe when the tumor is removed must be accurately determined. The CANS navigator enables precise localization of the suction tube during the transsphenoidal approach and allows safer and less-invasive surgery.

Key words: transsphenoidal surgery, computer-assisted neurosurgical navigational system, less-invasive surgery

Introduction

Transsphenoidal surgery requires precise orientation to avoid carotid artery injury. Previously intraoperative fluoroscopy has been used to monitor the transsphenoidal approach, but this technique can only provide sagittal guidance. Recent discussion of the transsphenoidal approach has described minimally invasive techniques such as endoscopy,[3] and computer-assisted image guidance may be another technique enabling less-invasive procedures. The computer-assisted neurosurgical (CANS) navigation system can provide both axial and coronal images, and thus obtain three-dimensional information for localization and surgical trajectory.[6-8] The present study examined the efficacy and drawbacks of the CANS navigation system for monitoring the transsphenoidal approach.

Patients and Methods

Nine patients with pituitary adenomas (mean age 58 years) underwent transsphenoidal surgery using the CANS navigation system (Shimadzu, Kyoto) between January 1999 and March 2001 (Table 1). Diagnostic imaging including computed tomography (CT) and magnetic resonance (MR) imaging was obtained. All approaches were sublabial. One procedure was reoperation. All patients had macroadenomas with suprasellar extension, two associated with pituitary apoplexy. The mean diameter of the masses was 3.8 cm. Four cases were asymptomatic adenomas with compression of the optic chiasma, of which three were detected at brain check-up.[5,9] Hor-

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Table 1 Patient demographic data

Case No.	Age	Sex	Symptom	Clinical characteristics
1	50	F	visual disturbance	apoplexy
2	69	F	asymptomatic	brain check-up
3	63	F	asymptomatic	brain check-up
4	56	M	asymptomatic	brain check-up
5	76	F	asymptomatic	
6	54	F	visual disturbance	
7	59	M	visual disturbance	
8	51	M	visual disturbance	apoplexy + reoperation
9	42	M	visual disturbance	acromegaly

monal studies revealed that eight cases were symptomatic and one case was a growth hormone-producing tumor presenting with acromegaly. Bone window CT revealed the nasal anatomy and provided useful information for the transsphenoidal approach.[10] Preoperative MR imaging was performed with four fiducial markers affixed to the bilateral mastoid tips, bregma, and nasion. The data were transferred and stored in the computer in the operating room via MO disk.

The CANS navigation system uses Windows-based software. Briefly, after the Mayfield head-holder was applied to the cranium, the magnetic sources were attached to the holder (Fig. 1). A magnetic sensor is mounted on the suction tube probe (Fig. 2). The navigator detects the magnetic field using the magnetic sources and calculates the tip position of the suction tube. The four markers were calibrated and registered with the active pointer using the monitor. The registration accuracy was within 2 mm. The tip of the suction tube with the sensor was placed on the sublabia before the incision to confirm the operative trajectory. Suction tubes with a sensor were used until the sphenoid sinus was entered. The location of the tip of the suction tube was confirmed on the monitor to maintain the correct direction (Fig. 3).

MR imaging was performed within 2 days postoperatively to evaluate the accuracy of the navigation system. The intraoperative position of the tip of the suction tube was recorded at a series of times to form the surgical track, which indicated the extent of tumor resection. The surgical track was shown as an accumulation of red spots superimposed on the postoperative MR image (Fig. 3).[6] Simulation study using a dry skull was performed to determine any discrepancy between the real targets and the MR image.

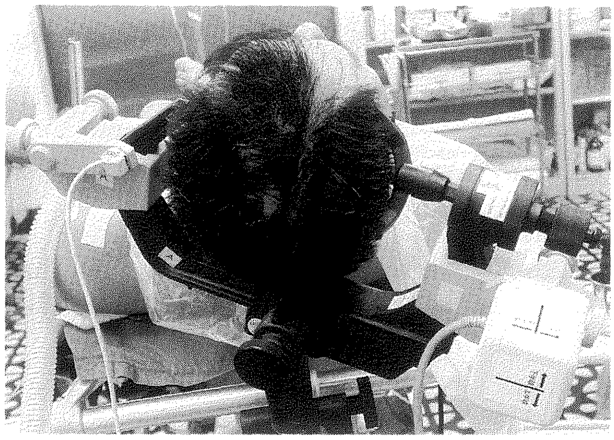

Fig. 1 Photograph showing the setup of the computer-assisted neurosurgical navigator. The patient's head is fixed with a Mayfield skull clamp to which the magnetic field source is attached.

Results

The mean setup time from the start of general anesthesia was 10 minutes. The mean operative time from incision to closure was 130 minutes. The system performed appropriately in all cases, and the registration accuracy was always within 2 mm. There was no difference in the localization of the internal carotid artery between the surgical track and the postoperative MR image in all cases. The simulation study using the dry skull showed a discrepancy of less than 1.5 mm between the real target for the internal carotid artery and the position of the tip of the suction tube. The navigation system was not useful for estimating the amount of suprasellar residual tumor because of the dislocation that occurred during the removal of the intrasellar tumor. Decompression of the optic nerve was satisfactory in all cases (Fig. 3). No intraoperative complications were associated with the use of this system. No patients developed postoperative complications or recurrence during the follow up from 1 to 30 months.

Discussion

Stereotactic guidance for transsphenoidal surgery is of little value to experienced neurosurgeons who are accustomed to fluoroscopic guidance. However, stereotactic guidance can be of great value for younger neurosurgeons, since there is a risk of carotid artery injury during the transsphenoidal approach. Skull base tumors such as pituitary adenoma are not displaced or distorted by operative pro-

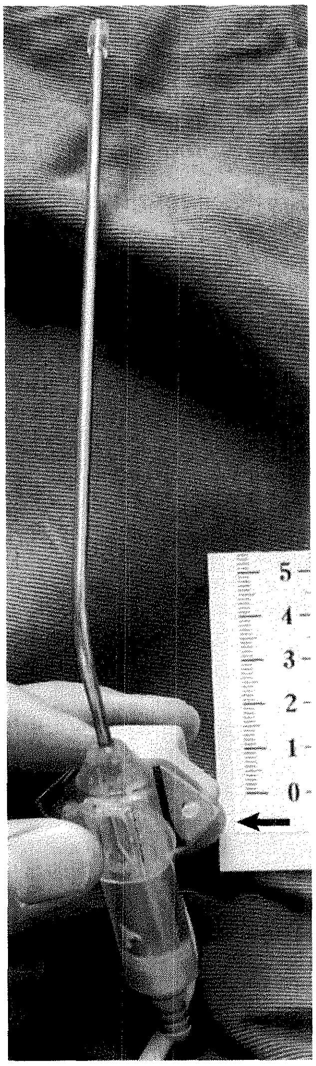

Fig. 2 **Photograph of the suction tube probe with the magnetic sensor. The arrow indicates the magnetic sensor.**

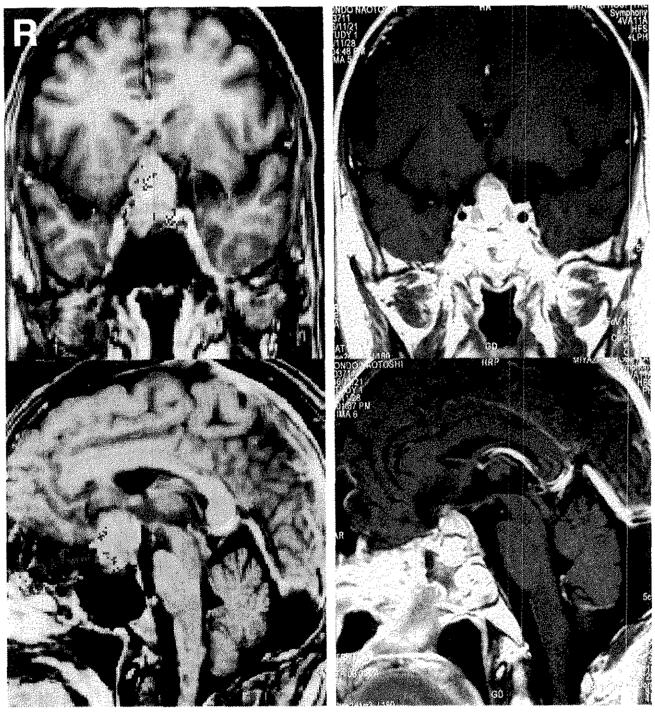

Fig. 3 **Case 7. Magnetic resonance images with the superimposed surgical track shown as red spots on the display, formed by plotting the positions of the suction tip (*left column*). Postoperative magnetic resonance images showing reduction of the tumor volume and decompression of the optic nerve (*right column*).**

cedures, so neurosurgical navigation is more useful for the operative management of pituitary adenoma. In this study, the CANS navigator could identify the location of the carotid artery during the procedure, and so will be a great asset for reoperations, in which landmarks are difficult to determine. The CANS navigator will be also valuable in cases of poor pneumatization of the sphenoid sinus or bony congenital parasellar anomalies.[1,4]

Various types of neurosurgical navigation systems are available to guide easy and safe access to sellar lesions. The multi-joint arm system is simple, but restricts the surgical field and the surgical procedures.[2] The optical sensor system provides spatial tracking but can be interrupted because surgeons or surgical instruments may intercept the light path.[1] The CANS navigator allows continuous and real-time monitoring throughout the operation in narrow operative fields, but this magnetic field modulation system can be disturbed by metallic instruments, so titanium or resin instruments are required to avoid drift of the three-dimensional digitizer. The error of the CANS navigation system can be decreased to 1 mm by using such surgical instruments.[8] Other factors affecting the accuracy include electromagnetic noise surrounding the magnetic field source and poor spatial precision of the scalp marker in calibrating the head position. A phantom study to compare the accuracy obtained using two-dimensional and three-dimensional data acquisitions indicated that more accurate stereotactic localization can be achieved with three-dimensional acquisition.[11] More accurate localization will provide a template for future studies of new navigation systems. However, brain distortion could affect the accuracy of the CANS navigator. The surgical track indicates the extent of tumor resection and can be superimposed on the postoperative MR image,[6] but is not useful for estimating the amount of suprasellar residual tumor when the tumor was removed. Thus, close attention is needed to determine the position of the probe as resection proceeds. Intraoperative CT or MR imaging will provide additional information about the shift of residual suprasellar tumor, which may allow more complete removal of macroadenoma.[1] Lack of data on residual tumors was not a serious problem in our series. Suprasellar tumor was frequently reached with the curved tip of the suction tube without a magnetic sensor and we were able to rely on the accuracy of the CANS navigator until resection proceeded. A further limitation is cost, which may prevent widespread use.

The CANS navigator enables the precise localization of the suction tube during the transsphenoidal approach and allows safer and less-invasive surgery for pituitary adenomas.

References

1) Abe M, Udono H, Tabuchi K, Uchino A: [Transsphenoidal surgery assisted by navigation system]. *No Shinkei Geka* 29(1): 31–38, 2001 (Jpn, with Eng abstract)

2) Burkey BB, Speyer MT, Maciunas RJ, Fitzpatrick M, Galloway RL, Allen GS: Sublabial, transseptal, transsphenoidal approach to the pituitary region guided by the ACUSTAR I system. *Otolaryngol Head Neck Surg* 118: 191–194, 1998

3) Cappabiance P, Alfieri A, Thermes S, Buonamassa S, Devitiis E: Instruments for endoscopic endonasal transsphenoidal surgery. *Neurosurgery* 45: 392–396, 1999

4) Elias WJ, Chadduck JB, Alden TD, Laws ER Jr: Frameless stereotaxy for transsphenoidal surgery. *Neurosurgery* 45: 271–275, 1999

5) Igarashi T, Saeki N, Yamaura A: Long-term magnetic resonance imaging follow-up of asymptomatic sellar tumors. Their natural history and surgical indications. *Neurol Med Chir (Tokyo)* 39: 592–599, 1999

6) Ikeda K, Shoin K, Taguchi H, Yamano J, Yamashita J: Cranionavigator combining a high-speed drill and a navigation system for skull base surgery: Technical note. *Neurol Med Chir (Tokyo)* 39: 701–708, 1999

7) Kato A, Yoshimine T, Hayakawa T: A frameless armless navigational system for computer assisted neurosurgery. *J Neurosurg* 74: 845–849, 1991

8) Kato A, Yoshimine T, Taniguchi M, Hirata M, Fujinaka T, Hirabuki N, Okumura T, Hayakawa T: CANS navigator for skull base surgery: usefulness of successive localizations and surgical track, *in* Tamaki N, Ehara K (eds): *Computer-Assisted Neurosurgery*. Tokyo, Springer-Verlag, 1997, pp 175–189

9) Nishizawa S, Ohta S, Yokoyama T, Uemura K: Therapeutic strategy for incidentally found pituitary tumors. *Neurosurgery* 43: 1344–1350, 1998

10) Saeki N, Yamaura A, Numata T, Hoshi S: Bone window CT evaluation of the nasal cavity for the transsphenoidal approach. *Br J Neurosurg* 13(3): 285–289, 1999

11) Walton L, Hampshire A, Forster D, Kemeny A: Stereotactic localization with magnetic resonance imaging: A phantom study to compare the accuracy obtained using two-dimensional and three-dimensional data acquisitions. *Neurosurgery* 41: 131–139, 1997

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Commentary on this paper appears on the next page.

Commentary

The authors describe a very practical method for computer-assisted navigational guidance during transsphenoidal surgery. They use a magnetic detection based system, calibrated to a sensor on a suction tip. The advantages of the system are that the setup and calibration time is very short, it uses Windows based software, and in use in a series of nine patients, the average error was less than 2 mm. Image guidance in transsphenoidal pituitary surgery is particularly useful in those patients who had prior operations wherein the normal anatomic landmarks may be missing or distorted. The device described here appears to be a very practical and straightforward method of assuring the accuracy of anatomic details, particularly in the mid-line, during transsphenoidal surgery.

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The authors have added a new dimension to transsphenoidal procedures — a third dimension. The first dimension was introduced by Dr. Gulot when he recreated the transsphenoidal approach with the use of radiofluoroscopy. His disciple, Dr. Jules Hardy, introduced the surgical microscope, a second dimension, and through it, good illumination. Now we see the introduction of modern neuronavigation, which adds to the safety of the procedure, circumventing the carotid arteries, procurement of the midline in difficult cases of sinus septation and congenital bony anomalies, reoperations, etc. We have also used a different navigation system in some cases in which we have struggled to find the midline in poorly aerated sinuses, difficult acromegalic skulls and Cushing's disease with normal sellae and sinus septal abnormalities, thus saving precious time in difficult approaches. We have the feeling that this will become routine in cases in which the CT bone windows show variations of bone structures and midline dislocations. Unfortunately, the method will not allow the determination of residual tumors. In such cases, addition of another dimension is sometimes necessary; assisted neuroendoscopy.

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The authors reported that usefulness of CANS (computer-assisted neurosurgical) navigation system in transsphenoidal pituitary surgery. Conventionally, x-ray fluoroscopy has been used for intraoperative orientation in the sagittal plane. Since the lateral deviation of the operative field cannot be monitored, we always take care to follow the midline. For this purpose, some structures, such as the anterior wall of the sphenoidal sinus (stump of the bony septum) and/or septi of the sphenoidal sinus are useful. Using these landmarks, we can correctly perform this approach in most cases. However, the navigation system can provide more accurate and scientific orientation in all directions. In addition, the space around the patient's head will become less crowded. Although transsphenoidal surgery is generally safe and less invasive, many kinds of complications have been reported. Carotid injury is the most dangerous and may become fatal. Of 1300 transsphenoidal surgeries, we have experienced carotid injury in three patients in whom the unilateral carotid artery deviated medially. Using the navigation system adequately, I think that this surgery will become much safer.

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