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신경항법장치를 이용한 두개저외과수술의 장점

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Benefits of skull base surgery using neuronavigation system

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Objective : Skull base tumors frequently encase or extend into vital neurovascular structures. Preoperative planning and intraoperative identification of anatomic landmarks is important in complex tumors since it helps avoid or minimize surgical morbidity. The purpose of this study was to describe the usefulness of recent advances of neuronavigation technology in the management of skull base tumors.

Patients and Methods : From March 2006 to May 2008, 32 patients underwent neuronavigation-assisted surgery for skull base tumors. A Stryker Leibinger system was used for neuronavigation.

Results : The use of neuronavigation was beneficial both pre-and intraoperatively. Gross total removal of the skull base tumors was accomplished in 29 out of 32 patients who were confirmed with postoperative CT and MRI scans. All tumors were removed completely as judged by intraoperative inspection in all patients except for three. The morbidity rates (18.8%) were different depending on the performed surgical approaches.

Conclusions : Image guidance facilitates complex approaches to various pathologies and enables mapping of skull base anatomy, especially during translesional dissection of complex tumors distorting and invading the neurovascular and osseous structures. Neuronavigation will enhance the efficacy and safety of skull base surgery. Skull base surgery is the best target for it because of the minimum possible brain shift.

Key Words *Neuronavigation, Skull base surgery, Image guidance.*

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Introduction

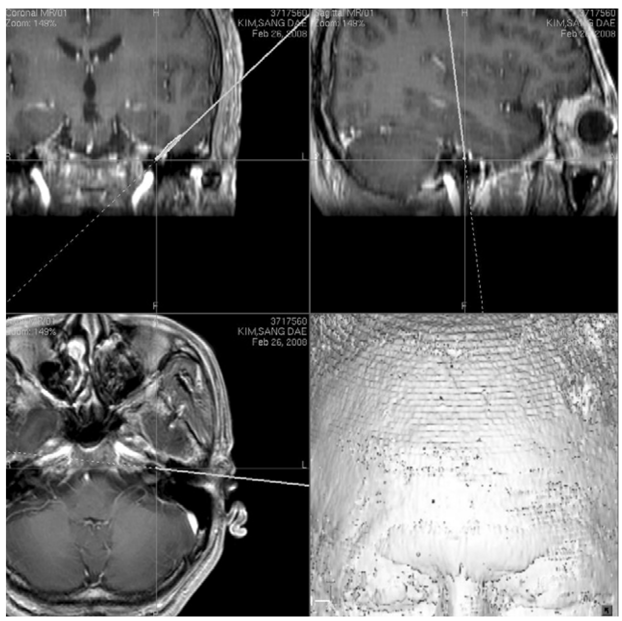
Tumors of the skull base frequently encase or extend into normal neural and vascular structures. Safe resection of the skull base lesions ultimately depends on the skill and experience of the surgeon, but evolving experience with image guidance over the past few years indicates the potential value of neuronavigation in skull base lesions.[4, 5, 12) Reported benefits include optimized positioning of the craniotomy site and the ability to define ideal vectors for approaching deep seated intrinsic lesions with minimal cortical trauma. The greatest value and versatility of surgical navigation in the skull base surgery is the fact that it provides guidance in planning the incision, determining the size of the craniotomy flap, and assessing the extent of bone resection at the skull base. Preoperative planning and intraoperative localization of anatomic landmarks are particularly important in complex skull base tumors and help avoid or minimize the surgical morbidity.

In this study, our preliminary experience with 35 consecutive patients operated on skull base lesions using an advanced image guidance system is reported.

Patients and Methods

From March 2006 to May 2008, 32 patients underwent neuronavigation-assisted surgery for skull base tumors (petroclival meningioma n=3, medial sphenoid wing meningioma n=3, olfactory groove meningioma n=2, tentorial meningioma n=3, foramen magnum menignioma n=1, acoustic schwannoma n=7, trigeminal schwannoma n=4, facial nerve schwannoma n=2, clival chordoma n=3, suprasellar gangioglioma n=1, pituitary stalk lymphoma n=1, brainstem hemangioblastoma n=1, and epidermoid cyst on the cerebellopontine angle n=1). A Stryker Leibinger system was used for neuronavigation. The decision as to which imaging modalities and which new tools of neuronavigation were to be applied, was guided by the approach considered, the nature of the lesion, and the structures at risk. For navigational planning, either computed tomography scans or T1-weighted magnetic resonance images with 2-mm thick axial slices with contrast injection were chosen. Preoperatively, CT or MR scans were performed after 5-6 adhesive fiducial markers were placed in a non-colinear fashion on the patient's head according to the surgical position. The CT or MR imaging data sets were transferred to the computer workstation at the planning room via a network. The computer reformatted the axial images into coronal and sagittal views and three-dimensional images. Intraoperative data for localization are acquired as one infrared camera activate and receive the signal emitted from reflective markers placed on a reference star array attached to a Mayfield clamp fixed to the patient's head. After patient positioning and application of the Mayfield head clamp, patient to image registration was performed using a non-sterile handheld pointer. Various reflective marker arrays were applied to surgical instruments so that they could be used as active pointers during the operation.

Fig. 1



Middle fossa approach for the left facial schwannoma. Intraoperative neuronavigation showing the precise localization of the tumor in the internal acoustic meatus.

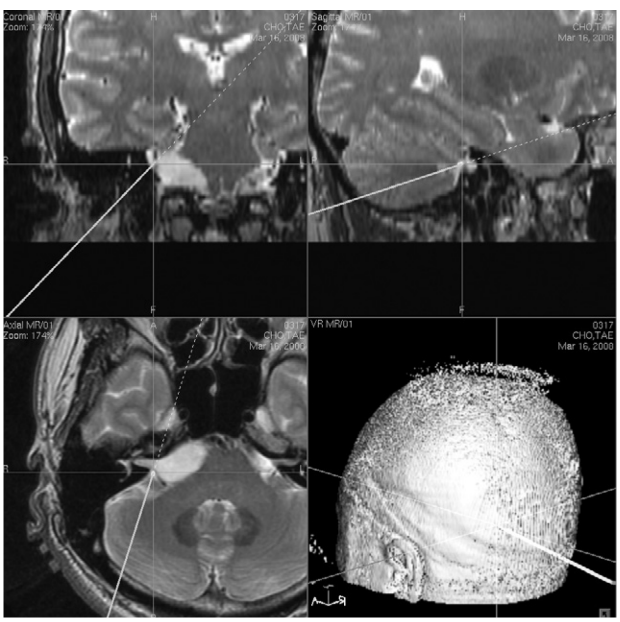
Results

The use of neuronavigation was beneficial both pre-and intraoperatively. The preoperative image preparation procedure and surgical planning were performed by a navigation-experienced neurosurgeon and took 10-15 minutes for data transfer and highlighting of tumors and anatomic landmarks. The intraoperative patient-to-image registration procedures were also performed by a navigation-experienced neurosurgeon and required 2 to 5 minutes with 5 to 6 skin fiducial markers. No pitfalls or technical difficulties were noted. Because of the relative immobility of the bone structures and/or the tumor, no significant deviation from the preoperative registration accuracy was noted at the end of the procedures. When compared to the intraoperative bony landmarks (for example, the clinoid processes) that were exposed during the surgical procedures it was estimated at 〈2mm in all our cases. As skull base tumors and basally located anatomic structures do not move due to CSF loss during dissection, a high localization accuracy of image guidance in skull base surgery can be assumed also for distorted vessels and neural structures. In the present study, gross total removal of the skull base tumors was accomplished in 29 out of 32 patients who were confirmed with postoperative CT and MRI scans. All tumors were removed completely as judged by intraoperative inspection in all patients except for three; in the first two patients with petroclival and medical sphenoid wing meningiomas, a piece of tumor that had infiltrated the cavernous sinus was left at the medical surface of the cavernous sinus. A third patient had a suprasellar ganglioglioma adherent to the hypothalamus. The morbidity rates (18.8%) were different depending on the performed surgical approaches.

Discussion

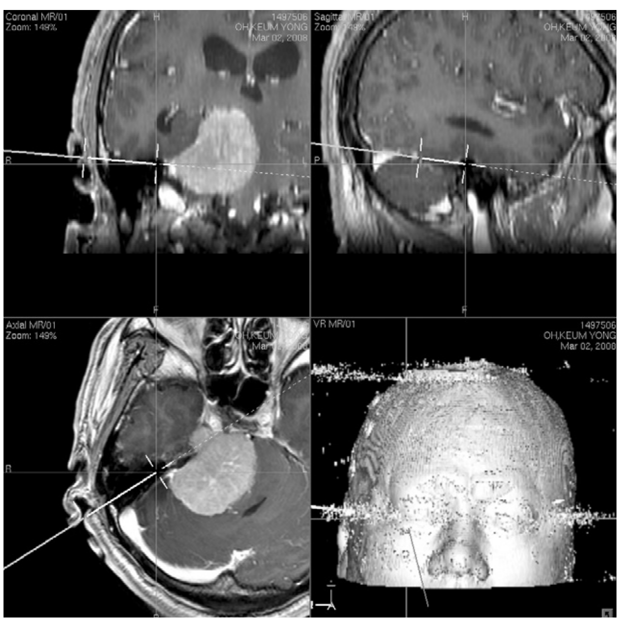
Operative neurosurgery has recently entered an exciting area of image-guided surgery or neuronavigation and application of this novel technology is beginning to have a significant impact in many ways on a variety of intracranial procedures. Neuronavigation was the most helpful for operations on deeply seated lesions, skull base tumors and

Fig. 2



Retrosigmoid approach for the right epidermoid cyst. Intraoperative neuronavigation demonstrating porus of the right internal acoustic meatus.

Fig. 3



Petrosal approach for the right petroclival meningioma. Neuronavigation enables precise preoperative planning for the tumor.

lesions in brain areas with high functionality.[2, 3, 11] With its high application accuracy, the system presented in this study provides useful feedback to the surgeon for preoperative anatomic orientation, precise planning and stimulation of the surgical approach, intraoperative navigation, avoidance of vital neurovascular structures, and assessment of the extent of possible resection. It provided anatomic structures and identifies the possible location of residual tumor. Skull base tumors benefit from computer-assisted neuronavigation, particularly while planning a critical approach.[6, 8-10] This technology can also help to identify prominent vascular and neural structures associated with skull base, in an effect to providing a visual warning that these structures are in the vicinity during an aggressive tumor resection.

The aim of this study was to evaluate the clinical accuracy, practicality, and impact of this navigation system on skull base procedures. Accuracy was always sufficient for image-guided surgery of any region of the skull base, with an average target registration error of below 1.2 mm. Although the impact of brain shift on image guidance and the need for intraoperative image updating is a controversial and unresolved issue, it is well known that skull base lesions are remarkable for the small extent of intraoperative brain shift. This factor predicts a high degree of reliability for neuronavigation in the treatment of skull base pathologies.[1] Preoperative changes with tumor resection, loss of CSF and patient position can limit the surgeon's access to the operative field. However, brain shift is not important in skull base tumor. Skull base surgery seems to be the ideal subspeciality for image-guidance technology. The tremendous advantage of neuronavigation becomes obvious during the treatment of skull base lesions more than in any other type of neurosurgery, because the osseous and neurovascular structures do not move during the surgical manipulation.

The latest generation of neuronavigation systems has come up with software improvements and new tools. Today, manual segmentation processes allow us to display vessels, nerves and tumor 2- or -dimensionally during surgery. In general, the tumor and the nervous tissue are more precisely visualized by MRI, whereas the bony structures (e.g, the temporal bone, including the middle ear, cochlea and internal auditory meatus) are better visualized by CT. Vascular structures are also better visualized by CT angiography or MR angiography. With appropriate preoperative image acquisition, image preparation, registration, and segmentation, CT and MR image fusion can be performed, leading to enhanced visualization and augmented reality.[7] For skull base surgery a fused image display can provide the surgeon with more precise information on the exact geometric relationship between the soft tissue stuctures seen on MRI, the bony structures observed on CT, and the vascular structures seen on CT or MR angiography.

The early identification of distorted and/or eroded vital neurovascular structures during the transtumoral dissection without anatomic landmarks is the most important benefit that is offered by neuronavigation. Therefore, we believe that the use of neuronavigation as presented in our series might additionally help to keep the complication rate low in patients suffering from extensive skull base lesions. The authors believe that careful selection of the most suitable, not standardized, but individually tailored approach, and knowledge about neurovascular structures will contribute to better outcomes in skull base surgery with lower morbidity and mortality.

In conclusion, although brain shift occurred following craniotomy and with brain retraction, the relative immobility of these lesions at the skull base permitted an accurate targeting of all lesions with an error range of 1.0-2.5 mm throughout the entire procedure. This relatively precise intraoperative feedback led to more accurate recognition of tumor landmarks. It is the authors' impression that a more aggressive resection of these lesions was achieved than could be without the device. The application of the neuronavigation system not only revealed benefits for operative planning, appreciation of anatomy, lesion location and the safety of surgery, but also greatly enhanced surgical confidence.

References

1. Dorward NL, Alberti O, Velani B, Gerrisen FA, Harkness WFJ, Kitchen ND, Thomas DGT. Postimaging brain distortion: Magnitude, correlates, and impact on neuronavigation. J Neurosurg 88:656–662, 1998
2. Eisenberg MB. The application of modern skull base techniques to routine neurosurgical problems. Contemp Neurosurg 22:1–7, 2000
3. Germano IM, Villalobos H, Silvers A. Postclinical use of the optical digitizer for intracranial neuronavigation. Neurosurgery 45:261–270, 1999
4. Golfinos JG, Fitzpatrick BC, Lawrence RS, Spetzler RF. Clinical use of a frameless stereotactic arm: Results of 325 cases. J Neurosurg 83:197–205, 1995
5. Gumprecht HK, Widenka DC, Lumenta CB. BrainLab Vectovision neuronavigation system: Technology and clinical experience in 131 cases. Neurosurgery 44:97–105, 1999
6. Hayashi N, Kurimoto M, Hirashima Y, Ikeda H, Shibata T, Tomita T, Endo S. Efficacy of navigation in skull base surgery using composite computer graphics of magnetic resonance and computed tomography images. Neurol Med Chir (Tokyo) 41:335–339, 2001
7. Hill DLG, Hawkes DJ, Crossman JE, Gleeson MJ, Cox TCS, Bracey EEC, Strong AJ, Graves P. Registration of MR and CT images for skull base surgery using point-like anatomical features. Br J Radiol 64:1030–1035, 1991
8. Kurtsoy A, Menku A, Tucer B, Oktem IS, Akdemir H. Neuronavigation in skull base tumors. Minim Invas Neurosurg 48:7–12, 2005
9. Rohde V, Spangenberg P, Reinges M, Gilsbach JM, Coenen VA. Advanced neuronavigation in skull base tumors and vascular lesions. Minim Invas Neurosurg 48:13–18, 2005
10. Sure U, Alberti O, Petermeyer M, Becker R, Bertalanffy H. Advanced image-guided skull base surgery. Surg Neurol 53:563–572, 2000
11. Wadley J, Dorward N, Kitchen N, Thomas D. Pre-operative planning and intra-operative guidance in modern neurosurgery: a review of 300 cases. Ann R Coll Surg Engl 81:217–225, 1999
12. Watanabe E, Watanabe T, Manaka S, Mayanagi Y, Takakura K. Three-dimensional digitizer (neuronavigator): New equipment for CT-guided stereotaxic surgery. Surg Neurol 27:543–547, 1987