Proceedings of the 2011 IEEE/ICME
International Conference on Complex Medical Engineering
May 22 - 25, Harbin, China

Skull Base Surgery using Navigation Microscope Integration System

Takashi Tamiya and Masahiko Kawanishi
Department of Neurological Surgery
Kagawa University Faculty of Medicine
Kita-gun, Kagawa, Japan
tamiya @kms.ac.jp

Shuxiang Guo
Graduate School of Engineering
Kagawa University
Takamatsu, Kagawa, Japan
guo@eng.kagawa-u.ac.jp

***Abstract* - Objective:** The use of intraoperative navigation system in neurosurgery has increased rapidly. The Neuronavigation Microscope Integration (NMI) system consists of a microscope (Zeiss, Germany) with StealthStation (Medotronic, U.S.A.) including light emitting diodes, a dynamic reference frame with light emitting diodes, an optical digitizer with camera array and a computer workstation. We investigated the usefulness of the NMI system for skull base surgery. **Patients and Methods:** Between April 2003 and August 2010, we used the NMI system in 136 patients undergoing skull base surgery including transsphenoidal surgery at Kagawa University Hospital. **Results:** Since the navigational informations could be superimposed into the microscope view, we obtained the accurate locations of tumor and normal anatomical structures before skin incision. During the operations, the surgeons did not need to turn away from the surgical field or to use bulky pointer. For the skull base surgery, the navigational informations were not affected by the brain shift during the operations. The deviations of registration assessment were within 2 mm and the real anatomical deviations were within 3 mm. For the transsphenoidal surgery, pituitary tumors could be removed safety without X-ray imaging. **Conclusion:** Our findings suggest that the NMI system can provide valuable and reliable intraoperative navigational informations in skull base surgery.

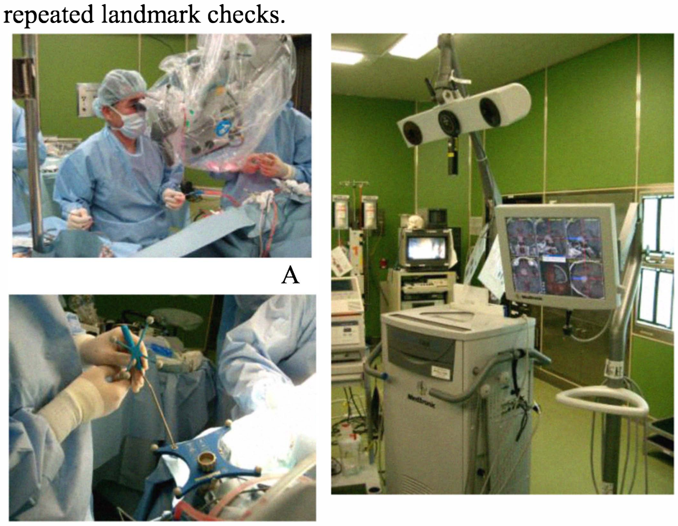
Index Terms* - *Skull base surgery, Frameless Neuronavigation, imaged-guided surgery

I. INTRODUCTION

The use of intraoperative navigation system in neurosurgery has increased rapidly. [1-9] Computer-assisted neuronavigation for intraoperative viewing of anatomical landmarks is being increasingly used for surgical removal of intracranial lesions. Neuronavigation simultaneously represents a complex, multimodal, information-based, widely adaptable technique, method, or device using frameless stereotaxy for precise intraoperative guidance, orientation, and localization, with consequently greater surgical precision and possibilities for preoperative virtual simulation and postoperative analysis of the surgical procedure.[1] The Neuronavigation Microscope Integration (NMI) system is composed of a microscope (Zeiss, Germany) and StealthStation® (Medtronic, U.S.A.) including light emitting diodes, a dynamic reference frame with light emitting diodes, an optical digitizer with camera array and a computer workstation. The object of the study was to evaluate the suitability and usefulness of the NMI system for skull base surgery.

II. CLINICAL MATERIALS AND METHODS

Intraoperative image guidance was achieved using a NMI system composed of a microscope (Zeiss, Germany) and StealthStation® (Medtronic, U.S.A.) (Figure 1). The registration is initiated using the disposable skin fiducial markers (Medtronic, Inc.) and surface landmarks, which are correlated with the same points on the three-dimensional CT/MRI surface reconstruction of the skin. The location of the navigation probe in the surgical field is displayed in the reformatted CT and MR data set and surgeons can visualize the patient's anatomy in the microscope view prior to and during surgery. The quality of registration is very important for obtaining accuracy from the system. Neuronavigational accuracy was documented by mean registration error and repeated landmark checks.



A B C

Fig. 1 The Neuronavigation Microscope Integration (NMI) system is composed of a microscope (A) and StealthStation (B & C) including light emitting diodes, a dynamic reference frame with light emitting diodes (B), an optical digitizer with camera array and a computer workstation(C).

Between April 2003 and August 2010, we used the NMI system in 98 patients undergoing skull base surgery including transsphenoidal surgery at Kagawa University Hospital. The skull base approaches comprised 10 frontobasal interhemispheric approach, 17 extradural temporopolar approach, 5 petrosal approach, 15 retrosigmoid suboccipital approach and 46 transsphenoidal approach.

Table 1.
Surgical approaches using Navigation Microscope Integration System

Surgical approaches	No of patients
Skull base surgery	98
Frontobasal approach	10
Extradural temporopolar approach	21
Petrosal approach (anterior, posterior)	6
Suboccipital approach	15
Transsphenoidal approach	46

III. RESULTS

Since the navigational informations could be superimposed into the microscope view, we obtained the accurate locations of tumor and normal anatomical structures before skin incision. CT and MRI fusion images are very useful for bone anatomy in skull base surgery. During the operations, the surgeons did not need to turn away from the surgical field or to use bulky pointer. For the skull base surgery, the navigational informations were not affected by the brain shift during the operations. The deviations of registration assessment were within 2 mm and the real anatomical deviations were within 3 mm. For the transsphenoidal surgery, pituitary tumors could be removed safety without X-ray imaging. Setting up the neuronavigation system required an additional 15 minutes of anaesthesia time. However, the neuronavigation guidance helped to save operation time by speeding the surgeon's orientation to the anatomy in the surgical field.

IV. ILLUSTRATIVE CASES

[Case 1]
The patient was a 56-year-old woman with recurrent chordoma in left cavernous sinus and left middle fossa. The tumor was gross totally removed by left extradural temporopolar approach using NMI system. Magnetic resonance images of the intraoperative navigational views and an intraoperative surgical microscopic view are shown in Figure 2.

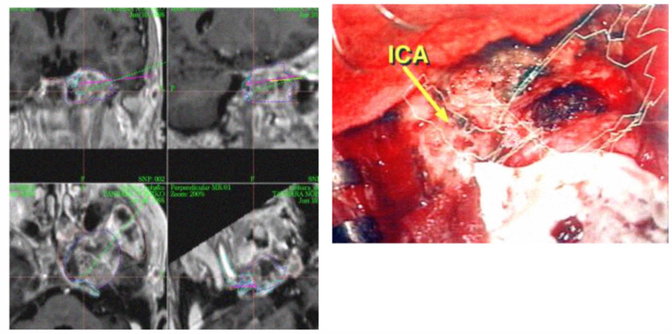


Figure 2. Magnetic resonance images of the intraoperative navigational views (left) and an intraoperative surgical microscopic view (right). The focus of the microscope indicates the internal carotid artery (ICA), which is located 5 mm deep from the tumor surface.

[Case 2]
The patient was a 52-year-old man with cavernous angioma in right cavernous sinus. The tumor was partially removed by left extradural temporopolar approach using NMI system. Magnetic resonance images of the intraoperative navigational views and an intraoperative surgical microscopic view are shown in Figure 3.

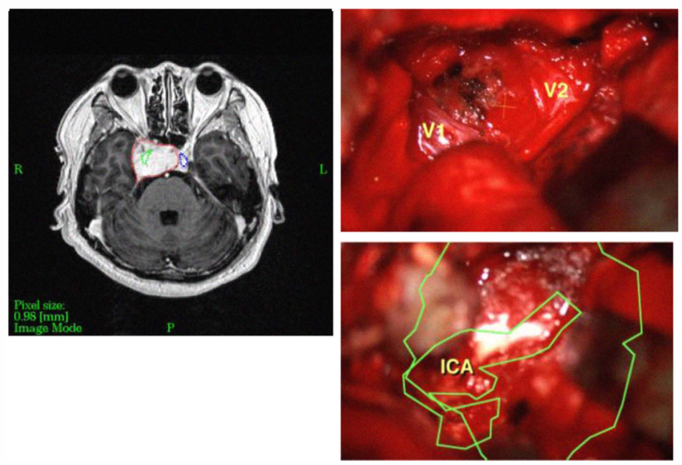


Figure 3. Axial view of T1-weighted image with Gd enhancement of the intraoperative navigational views (left) and intraoperative surgical microscopic views (right). Contours of the tumor and internal carotid artery (ICA) appeared on the microscope view when the focus was adjusted. V1, first branch of the trigeminal nerve; V2, second branch of the trigeminal nerve.

[Case 3]
The patient was a 60-year-old woman with right petroclival meningioma. The tumor was totally removed by right anterior transpetrosal approach using NMI system. Magnetic resonance images of the intraoperative navigational views and an intraoperative surgical microscopic view are shown in Figure 4.

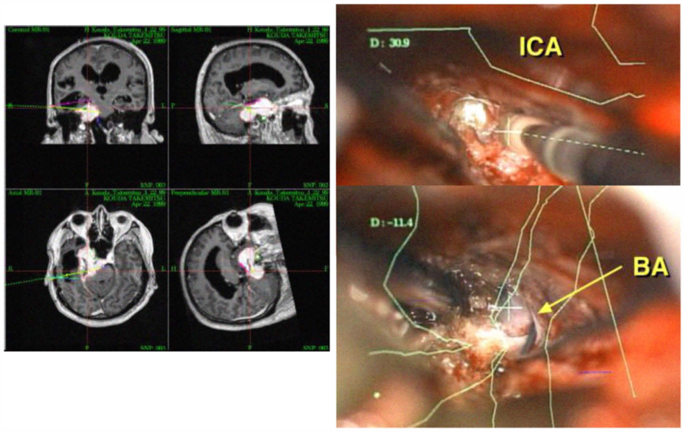


Figure 4. Magnetic resonance images of the intraoperative navigational views (left) and intraoperative surgical microscopic views (right). The locations of the tumor, internal carotid artery (ICA) and basilar artery (BA) coincided with their contours on microscopic views

V. DISCUSSION

Our study clearly demonstrates the usefulness of the NMI system for skull base surgery. The deviations of registration assessment were within 2 mm and the real anatomical deviations were within 3 mm in our study. Especially for the skull base surgery, the navigational informations were not affected by the brain shift during the operations. The accuracy and clinical usefulness of frameless systems based on an optical digitizer for neuronavigation have been assessed in various studies[8, 9]. Germano et al [3] found a mean accuracy of 2 mm in 170 neurosurgical procedures using the StealthStation™.

Since the navigational informations could be superimposed into the microscope view, we obtained the accurate locations of tumor and normal anatomical structures before skin incision. During the operations, the surgeons did not need to turn away from the surgical field or to use bulky pointer. Setting up the neuronavigation system required an additional several minutes of anaesthesia time. However, the neuronavigation guidance helped to save operation time by speeding the surgeon's orientation to the anatomy in the microscope view[2].

Current intraoperative imaging modalities include radiography, x-ray fluoroscopy, ultrasonography, and CT and MR imaging. With the incorporation of multimodality data sets with structural and functional information, image-guided neurosurgery has evolved into information-guided surgery[1]. The overlay of functional, diffusion, and perfusion data would constitute a virtual reality view of the brain, and continuous updating of this image would guide the neurosurgeon perfectly with the least possible margin of error in localizing, targeting, and revaluating the lesion and surrounding tissue intraoperatively[1].

Most likely, advancements in neuronavigator and MR scanner computer system software would make real-time, intraoperative MR imaging scans available[1]. The future trends of neuronavigation as integrated with intraoperative multimodality data, as well as with robotic systems are suspected.

Our findings suggest that the NMI system can provide valuable and reliable intraoperative navigational informations in skull base surgery.

Acknowledgment

This study was supported by a grant from the Foundation of Japan Ministry of Education, Science, Sports, Culture, and Technology (No. 22390277) and Kagawa University Characteristic Prior Research Fund 2010

Disclaimer

The author reports no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

References

[1] Enchev Y: Neuronavigation: geneology, reality, and prospects. Neurosurg Focus 27:E11, 2009

[2] Brinker T, Arango G, Kaminsky J, et al.: An experimental approach to image guided skull base surgery employing a microscope-based neuronavigation system. Acta Neurochir (Wien) 140: 883-889, 1998.

[3] Germano IM, Villalobos H, Silvers A, Post KD: Clinical use of the optical digitizer for intracranial neuronavigation. Neurosurgery 45:261-270, 1999.

[4] Golfinos JG, Fitzpatrick BC, Smith LR, et al.: Clinical use of a frameless stereotactic arm: results of 325 cases. J Neurosurg 83: 197-205, 1995

[5] Roessler K, Ungersboeck K, Dietrich W, et al.: Frameless stereotactic guided neurosurgery: clinical experience with an infrared based pointer device navigation system. Acta Neurochir (Wien) 139: 551-9, 1997

[6] Samii A, Brinker T, Kaminsky J, et al.: Navigation-guided opening of the internal auditory canal via the retrosigmoid route for acoustic neuroma surgery: cadaveric, radiological, and preliminary clinical study. Neurosurgery 47: 382-388, 2000

[7] Sipos EP, Tebo SA, Zinreich SJ, et al.: In vivo accuracy testing and clinical experience with the ISG Viewing Wand. Neurosurgery 39: 194-204, 1996

[8] Takizawa T, Soto S, Sanou A, et al.: Frameless isocentric stereotactic laser beam guide for image-directed microsurgery. Acta Neurochir (Wien) 125: 177-180, 1993

[9] Watanabe E, Mayanagi Y, Kosugi Y, et al.: Open surgery assisted by the neuronavigator, a stereotactic, articulated, sensitive arm. Neurosurgery 28: 792-800, 1991