

NEURONAVIGATION: A REVOLUTIONARY STEP OF NEUROSURGERY AND ITS EDUCATION

*S.Kağan Başarslan**, *Cüneyt Göçmez***

**Department of Neurosurgery, Mustafa Kemal University, School of Medicine, Hatay, Turkey*

***Department of Neurosurgery, Dicle University, School of Medicine, Diyarbakır, Turkey*

Abstract

Neuronavigation provides intraoperative orientation to the surgeon and helps in planning a precise surgical approach to the targetted lesion and defines the surrounding neurovascular structures. Incorporation of the functional data provided by computed tomography and magnetic resonance imaging or ultrasound with neuronavigation renders neurosurgeons to avoid the eloquent areas of the brain during surgery. An intraoperative images enable radical resection of the lesions, the possibility of immediate control for tumor remnants and updates of neuronavigation with these data to compensate for brain shift. This study reviews the pointer and microscope based navigational systems and also highlights the role and to show its indispensibility for a clean surgery with minimal morbidity.

Key words: Brain imaging, neuronavigation, neurosurgery

Geliş Tarihi / Received: 12.02.2014,

Kabul Tarihi / Accepted: 23.03.2014

INTRODUCTION

Neuronavigation is the set of computer assisted technologies used by neurosurgeons to guide or navigate within the borders of the skull or vertebral column during surgery. As a term neuronavigation is synonymous with image-guided surgery, computer-assisted or computer-aided surgery. This techniques dates back to the early 1900s and that gained popularity during the 1940s, especially with the development of surgery for the treatment of movement disorders such as Parkinson's disease and dystonias those needs to be reached certain exact locations. Over the past decade, brain surgeons have been accustomed to use intraoperative surgical navigation as a technological means to improve surgical outcomes and to reduce surgical morbidity (1).

More than 2,300 medical facilities worldwide utilize the neuronavigation systems to raise their patient care to the highest level. Neurosurgeans, more recently, have used surgical navigation for a widevariety of minimally invasive endoscopic approaches to the skull base. Althoughthe core technology has not changed meaningfully since its introduction, clinical experiences have grown considerably, and a few new applications such as CT, MR or ultrasound fusion have been introduced. In addition, a few reports have highlighted the principles of registration protocols, the initial step that supports all surgical navigation.

Neuronavigation provides intraoperative orientation to the surgeons and helps them in planning a precise surgical approach to the targetted lesion and defines the surrounding neurovascular structures. By incorporation of the functional data provided by functional MRI

and magnetoencephalography with neuronavigation, it also guides to avoid the eloquent areas of the brain during surgery (2). Neuronavigation provides the surgeon the ability to see a patient's anatomy in three dimensions and accurately pinpoint a location in the brain or spinal cord with the aid of diagnostic images such as computed tomography (CT) and magnetic resonance imaging (MRI), or intraoperative images like ultrasound, MRI, etc. It also enables surgeons to track instruments in relation to a patient's anatomy and track the anatomy itself during a surgical procedure.

Neuronavigation utilizes the principle of stereotaxis. The brain is considered as a geometric volume which can be divided by three imaginary intersecting spatial planes, orthogonal to each other (horizontal, frontal and sagittal) based on the Cartesian coordinate system. Any point within the brain can be specified by measuring its distance along these three intersecting planes. Neuronavigation provides a precise surgical guidance by referencing this coordinate system of the brain with a parallel coordinate system of the three-dimensional image data of the patient that is displayed on the console of the computer-workstation so that the medical images become point-to-point maps of the corresponding actual locations within the brain (3).



The StealthStation® S7® Surgical Navigation System from Medtronic is the seventh generation surgical navigation system. It offers various benefits to the surgeon such as intraoperative imaging integration, tracking technologies, 24 inch (61 cm) high-resolution and wide-screen monitor and easy access to pre-op exams. The StealthStation S7 comes with features such as 2-cart design for flexible positioning, 50% smaller footprint, high fidelity plus MP3-ready sound system, works in docked or undocked positions, AxiEM tracking system, ergonomically designed longer camera handle and laser button and uninterrupted power systems. Other features of the StealthStation S7 are that it works seamlessly with multiple intraoperative imaging systems like iMRI, iCT, C-arms, and the O-arm®

System, DICOM Query/ Retrieve and that it provides surgeons a choice between Medtronic's advanced optical surgical navigation camera or the AxiEM™ electromagnetic system.

The integration of functional imaging modalities, in particular, certain diagnostic modalities as well as magnetoencephalography, functional MRI and positron emission tomography (PET) with neuronavigation has permitted surgery in the vicinity of eloquent brain areas with minimum morbidity (2). The spatial accuracy of the modern neuronavigation system is further enhanced by the use of intraoperative MRI that provides real-time images to document the residual lesion and to assess for brain shift during surgery (4-7). This article is aimed to introduce neuronavigation and describe its necessity for contemporary neurosurgery.

HOW TO WORK A NEURONAVIGATION SYSTEM

1-The radiology technician takes a CT or MRI scan of the patient

Usually the evening before or day of the surgery, a radiology technician takes the first essential step a CT or MRI scan of the patient's anatomy. The CT Scan, which captures bony structures, is used most often for spine surgery, while an MRI, which creates a clear image of soft tissue, is preferred more often for brain surgery. Just as you navigate in a city on the basis of landmarks like a particularly tall building or a small stature, a surgeon uses landmarks for the image scan. In the case of the spine, the natural landmarks of the body such as part of spine bones (spinous process, etc) show up on a CT scan. But, the surface of the head is relatively featureless and may need some markers. Therefore, the physician will put some artificial landmarks on the patient's head to serve as markers. These tiny, donut-shaped sponges, known as fiducials, are coated with a special compound that appears on the MRI scan. If the scan is taken the night before surgery, the patient may be required to wear this special markers overnight because they must stay on until the registration (described in below)(figure 1).

2 - The surgeon builds a patient specific 3D model on the computer.

The surgeon downloads the image data from the scan of the anatomy into the computer. For brain surgery, the surgeon uses the data to build a three-dimensional model of the patient's unique anatomy to be viewed on a computer monitor. For spine surgery, the surgeon may go through this model-building process, unless the hospital uses software from manufacturer. This software makes the images available for immediate use by the surgeon and registers them automatically to the patient's body.

3 - The surgeon maps the computer model to the patient's body.

After anesthesia is administered but before the start of surgery, the surgeon maps the patient's anatomy to the 3D model of the scanned information. This process is called as

registration. The surgeon makes this by first touching the landmark on the patient with an image-guided pointer or probe. This can either be a natural landmark such as the outer point of the eye or between the two front teeth, or an artificial donut-shaped marker. Then someone touches same point on the screen. The camera for the image-guided surgery system transfers a signal from the probe to the computer to register the specific location being touched. Point by point on the patient's body and then on the monitor, the surgeon builds a correlation between the body and the screen image. By matching the scan to the real anatomy and using special image-guided instruments, the surgeon can orientate the location of the instrument tip in the body accurately during operation (fig.1 and 2).



Figure 1. The Registration of patient data and later on steps.

4 - The surgeon uses the image-guided system during surgery.

During surgery, the tip of the surgical instruments will be displayed dynamically as cross-sections in the three of the anatomical views on the monitor. As the surgeon moves the instruments, the views shift to show their new position promptly. This also enables the surgeon to visualize the proximity of the instruments to critical anatomic structures, such as the optic nerve, basilar arteries, etc.

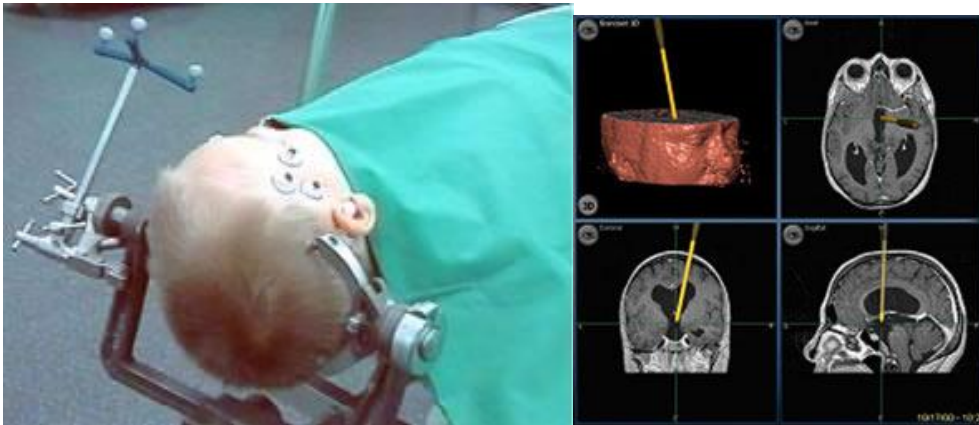


Figure 2. Showing the two and three dimensional views of a deep-seated lesion.

DISCUSSION

Neuronavigation was useful in providing orientation to the surgeon with sufficient application accuracy. It facilitates a precise planning of the craniotomy to the target small or subcortical lesions. Golfinos et al. have also elucidated its role in epilepsy surgery in predicting the length of the corpus callosum division in corpus callosotomy, in judging the posterior margin of the anterior temporal resection and in localizing the hippocampus; and, in endoscopic surgery, where an orientation within the ventricular system was provided (8).

Neuronavigation gives surgeons image-guided precision for delicate procedures like tumor removal, treatment of dystonias or deep brain stimulation. During tumor removal, navigation and intra-operative imaging allow the surgeon to see whether he or she has successfully removed the entire tumor and at the same time to avoid damage to surrounding healthy tissue. During deep brain stimulation, the surgeon is able to confidently and precisely target the exact point on the brain necessary for the treatment of Parkinson's disease or other neurological disorders. Absolute precision is also needed in spine surgery because of its proximity and relation to the spinal cord. Navigation helps the surgeon navigate through the bone, while avoiding the spinal cord and other nerves. This not only helps the surgeons perform a minimally invasive procedure, it allows them to visualize the exact incision or screw placement, and precisely track surgical instruments in relation to anatomy (9, 10).

An accurate and reliable neuronavigation requires a low system error and a high rate of concordance between the patient's preoperative three dimensional images and the surgical anatomy. This patient specific image registration can be achieved either by correlating fiducials on the skin or bone or by matching external rigid landmarks (8). In order to enhance the precision of registration, a surface-matching of the contours of the surface of head to the contours of the head visible on MRI can be also performed. During surgery, a system-check was obtained by localizing deep bony landmarks. The overall accuracy of the system was ascertained by comparing the fiducial coordinates on the displayed images to actual coordinates obtained from physical registration of the patient's head and noting the amount of deviation from each registered fiducial. Zinreich et al, defined the limits of the best accuracy (an average of 1-2mm) that can be expected in vivo, by testing the viewing wand system on a plastic model of the skull. Golfinos et al, achieved an accuracy of 2mm in 82% of their patients using CT images and 92% using MR images and felt that the more accurate registration with MR than CT was because of greater familiarity with MRI reconstruction in multiple planes. In the present series, the mean system accuracy obtained by using both the

fiducial registration as well as anatomical landmark-surface fitting computer algorithm was 1.81 mm, which is comparable to the accuracy reported in the other published series that ranges from 1.6mm to 3mm (1, 11-16)

There are, however, certain technical drawbacks that make its usefulness suboptimal. The probe of the stealth station is bulky restricting its manipulation under the microscope and its introduction into narrow operative fields like the cerebellopontine angle or the petrous bone. The view of the surgeon must change from the microscope to the workstation console, while localizing an anatomical structure with its probe which may inadvertently cause neurological trauma. the patient's head cannot be moved to gain a more optimal operating position as that would lead to loss of registration (14).

The deep tumor margin shift does not interfere with the accuracy of neuronavigation during surgery for the skull base lesions. In these cases, therefore, an assessment of shifts of important neurovascular structures surrounding the tumors is more useful than the measurement of brain surface shifts (13). Also serial intraoperative MRI provides an accurate basis for the computational analyses of brain deformations that may be used for intraoperative guidance during neuronavigation. Intraoperative three-dimensional ultrasonography various mathematical models and modification of the preoperative imaging data to match the real time deformed brain have also been proposed to evaluate and compensate for the inaccuracies that occur in neuronavigation due to brain shift during surgery (2).

The structures of the brain are very delicate and complex, and can easily be accidentally damaged by the surgical instruments. Damage can be devastating for the patient if even a small portion of healthy tissue is injured, with possible consequences including memory loss, speech or motor difficulties, personality change, various intellectual deficiencies, coma, and death. Neuronavigation helps to prevent these consequences by increasing the accuracy of the surgery, allowing doctors to pinpoint the target area. Brain surgeons are guided by neuronavigation, and it is not a replacement for any aspect of brain surgery. Choosing a competent surgeon is still critically important for a good neurosurgery outcome. Surgeons also need experience working with neuronavigation, since both the image on the monitor and the physical situation should be kept track of simultaneously, requiring concentration and a careful approach.

Consequently, using neuronavigation helps the surgeon accurately detect where he or she is working in the patient's body at every moment during surgery. This capability enables the surgeon to make smaller incisions and exact entry point. When trauma to the body is

minimized, of course, the patient may spend less time in recovery and may experience fewer complications. By enabling the surgeon to navigate through the delicate landscape of the brain more precisely, the surgeon can easily remove a lesion, possibly without impacting healthy tissue. During even closure, neuronavigation helps the surgeon align bones at just the right angle as natural anatomical position. This precise technology also enables the surgeon to go right to the problem, which may mean the patient spends less time on the operating table. Trauma, pain and scarring can be minimized due to smaller incisions and the surgeon's increased ability to avoid damaging healthy tissue. The precise technology can also mean better long-term results and decrease the need for repeat surgeries.

CONCLUSION

This study reviews to give an idea on the field of neuronavigation. Progressive advances in this technology will improve the cost-benefit ratio and the user-friendliness of the system and in the near future it may help to realize the aim of complete cytoreductive surgery with minimal morbidity. However, at the present state of knowledge, the benefits of neuronavigation only compliment the experience and knowledge of neuroanatomy of the surgeon and cannot act as a substitute for it. Therefore, a neuronavigation is one of the indispensable tools for its delicate procedures especially in neurosurgery.

REFERENCE

- 1- Ganslandt O, Behari S, Gralla J, Fahlbusch R, Nimsky C. Neuronavigation : concept, techniques and applications. *Neurol India* 2002;50:244
- 2- Nimsky C, Ganslandt O, Kober H et al. Integration of functional magnetic resonance imaging supported by magnetoencephalography in functional neuronavigation. *Neurosurgery* 1999; 44: 1249-1256.
- 3- Ganslandt O, Fahlbusch R, Nimsky C et al. Functional neuronavigation with magnetoencephalography outcome in 50 patients with lesions around the motor cortex. *J Neurosurg* 1999; 91: 73-79.
- 4- Black P McL, Alexander E III, Martin C et al. Craniotomy for tumor treatment in an intraoperative magnetic resonance imaging unit. *Neurosurgery* 1999; 45 : 423-433.
- 5- Kamada K, Takeuchi F, Kuriki S et al. Functional neurosurgical stimulation with brain surface magnetic resonance imaging and magnetoencephalography. *Neurosurgery* 1993; 33: 269-273.

- 6- Nimsky C, Ganslandt O, Fahlbusch R et al. Intraoperative use of the Magnetom Open in neurosurgery *Electromedica* 1999; 67: 2-8.
- 7- Nimsky C, Ganslandt O, Cerny S et al. Quantification of, visualization of, and compensation for brain shift using intraoperative magnetic resonance imaging . *Neurosurgery* 2000; 47: 1070-1080.
- 8- Golfinos JG, Fitzpatrick BC, Smith LR et al. Clinical use of a frameless stereotactic arm: results of 325 cases. *J Neurosurg* 1995; 83: 197-205
- 9- Laborde G, Klimek L, Harder A et al. Frameless stereotactic drainage of intracranial abscesses. *Surg Neurol* 1993; 40: 16-21.
- 10- Nimsky C, Ganslandt O, Kober H et al. Intraoperative magnetic resonance imaging combined with neuronavigation: a new concept. *Neurosurgery* 2001; 48: 1082-1091
- 11- Zinreich SJ, Tebo SA, Long DM et al. Frameless stereotaxic integration of CT imaging data: accuracy and initial applications. *Radiology* 1993; 188: 735-742.
- 12- Black P McL, Alexander E III, Martin C et al. Craniotomy for tumor treatment in an intraoperative magnetic resonance imaging unit. *Neurosurgery* 1999; 45: 423-433.
- 13- Nabavi A, Black PM, Gering DL et al. Serial intraoperative magnetic resonance imaging of brain shift. *Neurosurgery* 2001; 48: 787-798
- 14- Sekhar LN, Chanda A. Comments on: Sure U, Alberti O, Petermeyer M, et al: Advanced image-guided skull base surgery. *Surg Neurol* 2000; 53: 563-572.
- 15- Bucholz RD, Yeh DD, Trobaugh J et al. The correction of stereotactic inaccuracy caused by brain shift using an intraoperative ultrasound device. In: *Medicine and Medical Robotics and Computer-assisted Surgery*, Grenoble, France 1997, Troccaz J, Grimson E, Mosges R (eds): Springer-Verlag, Berlin 1997; 459-466.
- 16- Watanabe E, Watanabe T, et al. Threedimensional digitizer (neuronavigator). New equipment for computer tomography-guided stereotactic surgery. *Surg Neurol* 1987; 27 : 543-547.