Keeping up with technology

Application of neuronavigation in Neurosurgery at King Hussein Medical Center, Jordan

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ABSTRACT

Objective
To evaluate use of neuronavigation in interdisciplinary surgery for complicated tumors or trauma of the anterior or lateral skull base.

Methods
Neuronavigation image guidance was used in the surgical management of 40 patients, one with large orbital roof meningioma causing proptosis and visual deterioration, and the others with small cortical tumor, motor strip lesion and larger size tumors.

Results
The patients underwent successful cranial surgery aided by intraoperative neuronavigation. The orbital roof meningioma was removed completely with no damage to the frontal sinus and motor strip lesions without neurological deficit and with good cosmetic result.

Conclusion
Image-guided neuronavigation in our cases allowed for safe and precise surgery, with avoidance of complications. (Rawal Med J 2010;35: ).

Keywords
Intraoperative image-guided neurosurgery, neuronavigation.

INTRODUCTION

Currently, neuronavigation is an indivisible and indispensable part of the neurosurgical reality with a significant potential impact in each neurosurgical procedure. The history of neuronavigation is less than three decades, but is full of highly promising achievements. Registration is an optical-based system, which uses an infrared camera array to monitor instrument and head position. This camera tracks the location of light-emitting diodes (LEDs) mounted to surgical instruments and to a reference arch attached to the Mayfield head clamp. Throughout the entire surgery, rigid fixation is necessary to maintain the correlation between space coordinates of the navigation system and the patient's coordinates as defined during registration. The quality of registration is very important for obtaining accuracy from the system. Neuronavigational accuracy has been documented by mean registration error and repeated landmark checks.

PATIENTS

Forty patients (28 women, 12 men; mean age, 39.5 years; range 18 to 61) underwent neurosurgical procedures using neuronavigation guidance. One patients had orbital roof meningioma. Two had cerebellopontine angle tumor, 22 had different size and sites of brain meningioma and 16 had fronto-parietal temporal glioma. All patients underwent postoperative contrast-enhanced radiological studies to assess the degree of surgical resection.
RESULTS
The neurosurgical approaches included frontal, coronal, and parietotemporal access. The neuronavigation allowed gross tumor resection in thirty five of the forty patients, helping to preserve important anatomical structures surrounding the tumor such as motor cortex and neurovascular structures. Incomplete resection was achieved in five patients due to vascular encasement and extension into eloquent structures. Use of the neuronavigation system facilitated bony reconstruction of the anterior and lateral skull base, resulting in symmetrical and clinically satisfying outcomes. Especially when bone substitutes were used, the contour could be corrected more easily by comparing the radiological data with the clinical impression.

Accuracy of the Neuronavigation System
At the beginning of the operation, the neuronavigation system provided an accuracy of registration of 0.61 to 2.70 mm (mean, 1.21 mm±0.72 mm). Landmark checks during surgery documented that the Stealth System remained stable. The quality of the initial registration is monitored by the root mean square (RMS)-error given by the software. The registration is then checked with known anatomical landmarks.

ILLUSTRATIVE CASES
Case 1
A 32 year old female presented with progressive headache and proptosis of the left eye. Magnetic resonance image (MRI) showed left orbital roof meningioma (Fig. A). Neuronavigation system was used to guide tumor removal, to identify surrounding critical structures and frontal sinus (Fig. B). The frontal sinus was outlined prior to craniotomy with the help of neuronavigation to avoid opening it.
Fig. A. MRI shows left orbital roof meningioma, second slide shows intraoperative outline of the tumor.

Fig. B. The frontal sinus and the tumor were drawn on the skin to avoid opening the sinus with the help of neuronavigation.

Fig. C. Shoot slide for intraoperative registration.

Case 2
A 40 year old male who had experienced progressive loss of hearing and tinnitus for one year. MRI revealed left cerebellopontine angle (CPA) acoustic neuroma and audiogram showed absence of hearing in the left ear. Neuronavigation supported and facilitated identifying the transverse and sigmoid sinus during craniotomy.

Fig. D. Transverse, sigmoid sinuses and the tumor were outline during CPA craniotomy using neuronavigation.
Case 3
A 20 year old female who presented with seizures. MRI revealed a left small temporal lobe tumor (Fig. E). Neuronavigation supported and facilitated identifying the small tumor (Fig. F).

Fig. E. MRI shows small left temporal tumor.

Fig. F. The tumor was localized before craniotomy by neuronavigation.

Case 4
A 51 year old male who had experienced headache, seizures and progressive left sided weakness for six months had a right parietal brain tumor close to the motor strip. Craniotomy confirmed the diagnosis of brain meningioma. (Fig. G). Neuronavigation helped us to identify the motor strip and limited our craniotomy exactly over the tumor (Fig. H).
Fig. G. MRI shows motor cortex brain meningioma.

Fig. H. The neuronavigation supported us to outline the tumor on the scalp and the bone to avoid the motor cortex.

Case 5
A 35 year old male patient presented to us with history of headache and seizures. MRI revealed a left small parietal tumor Neuronavigation minimised our craniotomy over the tumor without removing much bone. (Fig. K)
DISCUSSION
Neuronavigation provides intraoperative orientation to the surgeon, helps in planning a precise surgical approach to the targetted lesion and defines the surrounding neurovascular structures. Incorporation of the functional data provided by functional MRI and magnetoencephalography (MEG) with neuronavigation helps to avoid the eloquent areas of the brain during surgery. An intraoperative MRI enables radical resection of the lesions, the possibility of immediate control for tumor remnants and updates of neuronavigation with intraoperative images to compensate for brain shift. Neuronavigation has been useful in providing orientation to the surgeon with sufficient application accuracy. It facilitated a precise planning of the craniotomy and of the surgical vector to the targetted small, subcortical lesions; in astrocytomas, it helped to define the tumor margins and the limits of resection. In skull base lesions, it was useful in localizing encased and displaced vascular structures, the tumor extension into various brain crevices and the position of osseous landmarks. Golfinos and colleagues have also elucidated its role in epilepsy surgery in predicting the length of the corpus callosum division in corpus callosectomy, 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.

An accurate and reliable neuronavigation requires a low system error and a high rate of congruence between the patient's preoperative three dimensional images and the surgical anatomy. This patient-to-image registration can be achieved either by correlating fiducials on the skin or bone or by matching external rigid landmarks. In order to enhance the accuracy of registration in our patients, a surface-matching of the contours of the surface of head to the contours of the head visible on MRI was also performed. During surgery, a system-check was performed by localizing deep bony landmarks. Zinreich et al, defined the limits of the best accuracy of an average of 1-2mm. 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 case of lesions of the posterior fossa, however, the error in accuracy was much higher.
Conclusion
In our study, the applications of neuronavigation and image guidance allowed for safe and more precise lesion targeting. Progressive advances in technology will improve the cost-benefit ratio of the system and in the near future it may help to realize the aim of complete cytoreductive surgery with minimal morbidity. It may be a useful tool to enhance surgeon confidence and optimize surgical results.

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REFERENCES