

Virtual Navigation - A New Modality in Perioperative Brain Tumor Imaging

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Summary

Ultrasound (US) is gradually gaining in importance in neurosurgery alongside perioperative CT/MRI as a useful tool for imaging brain lesions pre- and perioperatively. The basic examination currently involves two-dimensional ultrasound imaging (B-mode). To improve and refine orientation within the operating field, 3D ultrasound imaging using computer-aided reconstruction of a series of consecutive 2D US sections similar to CT/MRI was developed in the late 1980s. Although the 3D ultrasound model significantly improved control over the procedure itself, perioperative MRI remained the most precise method, especially when small, deeply located brain lesions (cavernomas, small gliomas and similar lesions) were concerned. Norwegian neurosurgeons developed SonoWand,

a separate navigation system as an alternative to perioperative MRI, making it possible to fuse the image by linking the findings of preoperative navigation (CT/MRI) with those obtained using perioperative ultrasound. Such a fusion of images seems to successfully combine the advantages of both modalities into a single image and for most patients represents a perfect alternative to perioperative MRI. Smart Fusion, the virtual navigation developed by Toshiba is the next step to further improve image fusion. Here, a separate navigation system is integrated directly into the ultrasound system (Toshiba Aplio 500). Before the intervention, a study of preoperative CT/ MRI investigations is downloaded in DICOM 3 format; the ultrasound is connected to an electro-magnetic field transmitter and the ultrasound probe is connected to a sensor

that registers position within the electromagnetic field. Once reference points have been registered, the system can simultaneously provide real-time ultrasound images and the corresponding CT/MRI images from the downloaded dataset. Thus the probe can be used for preoperative examination and planning and for perioperative imaging with or without fusing both modalities. Our Department of Neurosurgery, KNTB Zlín, in cooperation with the Department of Neurosurgery, UH Ostrava, has been testing this method of perioperative imaging in brain tumor resections since June 2011. The first tests were conducted with a different vendor's system. We started using the Toshiba technology in May 2012.



Case history

Resection of anterior cranial fossa meningioma (Fig. 1)

The patient presented with headaches which she said she had been experiencing for several years, more recently accompanied by changes in behavior (depression, slowed mental reactions). She was examined by a neurologist and based on a CT scan with contrast medium she was diagnosed with anterior cranial fossa meningioma (olfactory groove) 2 x 2 x 3 cm in size, with peri-focal edema of the adjacent cerebral tissue (Fig. 1). An implanted cardiac pacemaker prohibited the use of MRI. In view of the deep location and size of the tumor, we decided to perform a right-sided frontotemporal craniotomy and used the Toshiba fusion imaging solution, both to improve the precision of the access trajectory and to control the degree of resection radicality in relation to the surrounding cerebral tissue.

Prior to the procedure, data from the CT scan in the corresponding format were transferred to the ultrasound system. Once the patient was under

general anesthesia and her head was fixed in a three-point clamp, we placed the electromagnetic field generator at a distance of approx. 60 cm from the planned craniotomy site. We attached a position sensor on a micro-convex ultrasound probe (3–6 MHz) and connected all the sections using cables (ultrasound – transmitter – sensor) (Fig. 2). After routine preoperative preparation, we performed a standard frontotemporal craniotomy on the right side. Having lifted off the bone flap, we obtained a fusion of the CT and 2D ultrasound images in two steps. We first registered the perpendicular/transverse position of the sensor in relation to the patient’s body axis. We then correlated the CT/US images according to the reference points that were well visualized in both types of imaging. In our patient, the reference structures included the falx cerebri, the 3rd ventricle and the crista galli. Having confirmed the correlation of the incision, the system then self-centered both images in the remaining two X and Y axes (left-right and ventro-dorsal). Using the resulting fusion images, we navigated an optimal access trajectory below the frontal lobe towards the expansion in the mid-section of the olfactory groove (Fig. 3).

Movement registered by the probe in the electromagnetic field resulted in the system providing continuous CT/US sections in all three planes. We then conducted a radical resection of the expansion using microscopic surgical techniques under perioperative ultrasound control. The tumor was removed in total without any damage to the surrounding brain tissue as demonstrated by subsequent postoperative CT scans and the uncomplicated postoperative course (Fig. 4).

Discussion

Image fusion during brain tissue surgery obtained using virtual navigation technology can link the characteristics of preoperative navigation and perioperative ultrasound imaging within a single system. This can significantly facilitate planning of access trajectories at the outset of surgery as well as orientation in the operative field and its surroundings during the procedure itself. Based on our first experience with the Toshiba system, we are in the position to describe the advantages and disadvantages of this technology compared to other imaging techniques. In our view, the major advantage is better orientation due to the high-

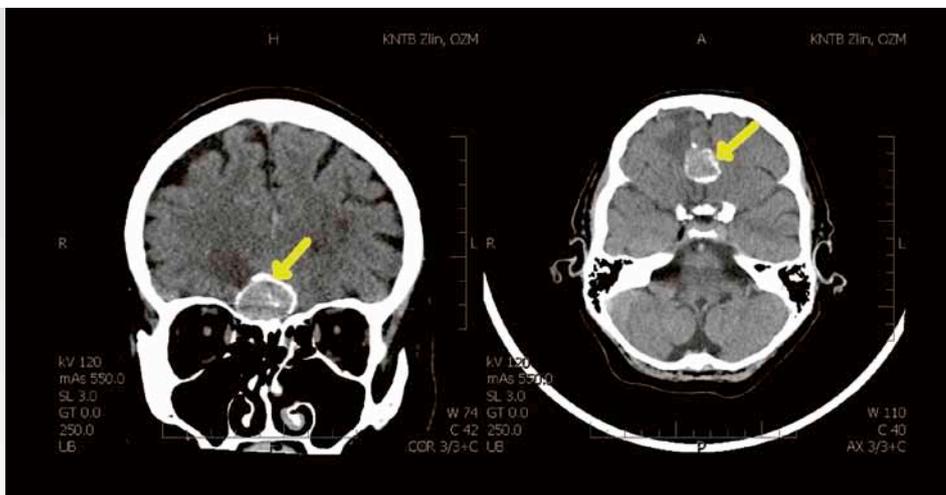


Fig. 1: Preoperative contrast CT scan (olfactory groove meningioma)



Fig. 2: Toshiba solution – ultrasound probe with position sensor and perioperative fusion imaging

quality imaging during navigation and the procedure itself obtained using the ultrasound probe and the position detector in all modalities compared to the separate use of navigation and perioperative ultrasound. A further advantage is the fact that this set-up takes less space in the operating theatre as the downloaded preoperative results can be directly transferred into the ultrasound system and the electromagnetic field source is smaller than systems that use optical navigation. Moreover, the ultrasound and the navigation system can be used independently for other types of surgery (e. g. navigation of targeted biopsy, possible use of the ultrasound equipment itself outside of the operating theatre for standard ultrasound diagnostics). Last but not least, the costs of the entire Smart Fusion (Toshiba sonograph + navigation) system are comparable to the costs of a high-performance single-purpose ultrasound system.

Nevertheless, for routine use under the stringent conditions of the neurosurgery operating theater the virtual navigation solution will require further improvements in the mechanical adaptation of the technical accessories. Especially improved

positioning of the electromagnetic field generator, including the option to attach it directly to the operating table, would be desirable. We would also welcome more extensive data compatibility for pre-registered CT and MRI data. Finally – although working with the system's very small micro-convex transducer has proven to be feasible – we believe that image fusion on the standard transcranial probe could further improve preoperative navigation in craniotomy.

Provided that these improvements become available, the technology of virtual navigation will certainly have the potential to become a fully-fledged alternative to the currently used costly and bulky navigation and imaging solutions and perioperative MRI.

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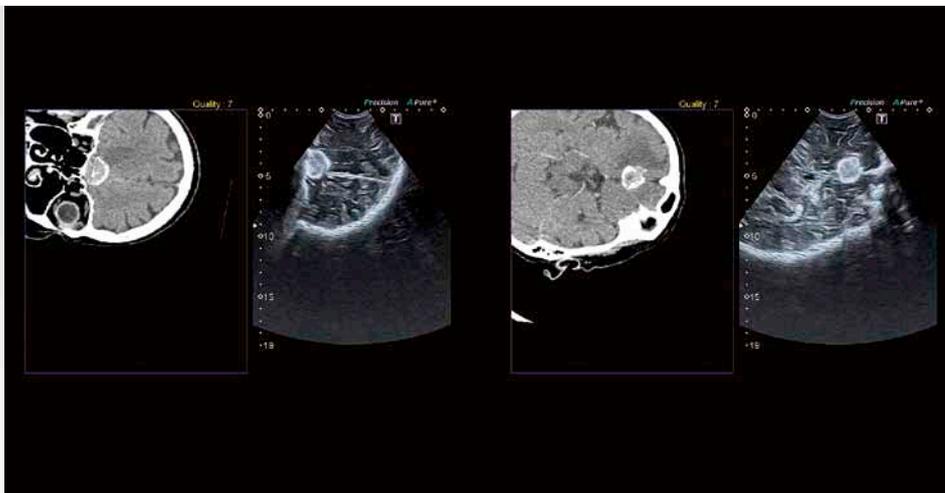


Fig. 3: Fusion of CT/ultrasound images during perioperative trajectory planning in the coronal and horizontal planes

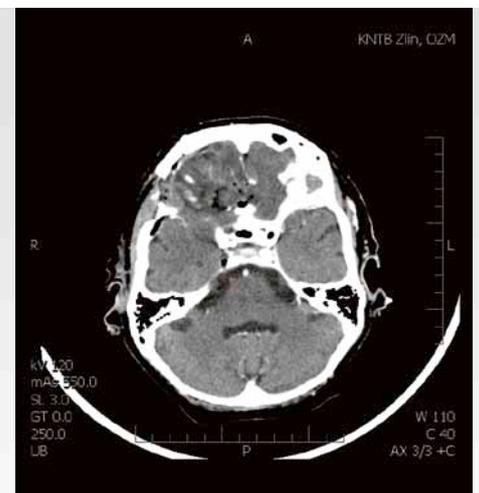


Fig. 4: Follow-up contrast CT scan 24 h after surgery (radical resection with perifocal edema)

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