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Technical Notes

Using virtual lines of navigation for a successful transcortical approach

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ABSTRACT

Background: Neuronavigation systems have become essential tools in image-guided neurosurgery that aid in the accurate resection of brain tumors. Recent advancements to these devices can indicate the precise location of lesions but can also project an augmented reality (AR) image on the microscope eyepiece to facilitate a successful surgical operation. Although the transcortical approach is a very popular method in neurosurgery, it can lead to disorientation and can cause unnecessary brain damage when the distance from the brain surface to the lesion is long. Herein, we report on an actual case in which a virtual line from AR images was used to assist the transcortical approach.

Methods: A virtual line connecting the entry point and the target point, which were set as the navigation route, was created using Stealth station S7® (Medtronic, Minneapolis, USA). This line was projected as an AR image on the microscope eyepiece. It was possible to reach the target point by proceeding through the white matter along the displayed virtual line.

Results: The lesion was reached within a short duration using virtual line without disorientation.

Conclusion: Setting a virtual line as an AR image using neuronavigation is a simple and accurate method that can effectively support the conventional transcortical approach.

Keywords: Augmented reality, Neuronavigation system, Transcortical approach, Virtual line

INTRODUCTION

Since the first reported use of a intraoperative frameless stereotactic navigation device by Roberts *et al.*,[16] neuronavigation has become an indispensable device for various neurosurgical procedures. Recent advancements in this field have allowed image-guided neurosurgery to indicate the precise location of lesions, but also to project preoperatively evaluated blood vessels and nerve fibers.[7,12,13] Using this projection function, the lesion can be displayed as an augmented reality (AR) image on the microscope eyepiece and monitors.[10] Satoh *et al*. reported AR systems in image-guided neurosurgery could significantly aid in the accurate resection of both superficial and deep surgical tumors with either transcortical or interhemispheric approaches.[17]

In neurosurgery, a transcortical approach, including the high parietal approach, is used for deeply located lesions, such as intraventricular tumors. However, this approach may lead to disorientation and can even cause unnecessary brain damage when the distance from the brain surface to the lesion is long. Although some techniques have been reported, which may prevent damage to the surrounding brain tissues,[14,15] very few of them have the capacity to approach the lesion.

In our institution, we use a target-setting system that is installed in our neuronavigation system to display the approaching virtual route on the microscope eyepiece, and thus guide a virtual route to the lesion when performing a transcortical approach. Contrary to the conventional method of creating surgical images from preoperative images with a navigation system, this report presents a simple and easy method that displays surgical plans as virtual lines.

CASE PRESENTATION

A 69-year-old female patient presented to an outpatient clinic with severe headache. The patient had a medical history of colon and breast cancer which had already been treated successfully. At the time of outpatient consultation, she only complained of headaches, and no neurological symptoms were observed. Computed tomography (CT) revealed hemorrhage from the posterior horn of the left-sided lateral ventricle to the trigone [Figure 1a]. Magnetic resonance imaging (MRI) showed a 17-mm mass with hemorrhage at the same site. The lesion appeared hypointense on T1-weighted, T2-weighted, fluid-attenuated inversion recovery images, and diffusion-weighted imaging. Strong homogeneous enhancement was seen following contrast administration [Figures 1b-f]. We used non-steroidal anti-inflammatory drugs to control the patient's headache and followed up with MRI for 2 months. The second MRI examination revealed that the lesion had grown to 23 mm along with presence of edema in the white matter around the posterior horn of the left lateral ventricle. Due to the rapid mass increase within a short period of time, a malignant tumor was suspected, and the patient was subsequently referred to our institution. Differential diagnosis included a meningioma, a cavernous angioma, or a metastatic brain tumor for this mass lesion, and surgery was planned to establish a pathological diagnosis and improve mass effect-related symptoms.

Surgical treatment

A high parietal approach was selected after considering the patient's postoperative neurological complications. The patient underwent surgery in the prone position. In general, our institution uses the Stealth station S7® (Medtronic, Minneapolis, USA) as the intraoperative navigation device. Fusion of navigation information and intraoperative CT (SOMATOM Definition, Siemens, Munich, Germany) were employed for registration navigation. Next, areas of the postcentral gyrus, the left-sided lateral ventricle, and the mass lesion were extracted, which could be displayed as AR images on the microscope eyepiece. The approximate location of any marked structures could be confirmed from the surface of the patient's skin before surgery by projecting AR images on the microscope eyepiece with this structure information. After craniotomy, the central sulcus and the postcentral gyrus were confirmed with a sensory evoked potential (SEP) of Neuromaster G1® (NIHON KOHDEN, Tokyo, Japan). Using navigation program for a needle biopsy in our Stealth station, the entry point was set at the point of entry superior parietal lobule, and the target point was set at the lesion in the left lateral ventricle. A line connecting these two points is drawn as the virtual line of the entry route [Figures 2a-d]. Structures of the brain surface were confirmed with AR images over the dura matter after craniotomy [Figure 3a]. A point of cortical incision was plotted on the surface of the superior parietal lobule, and the position of the microscope was adjusted to overlap this point and the entry point [Figure 3b]. The virtual line was displayed on the microscope eyepiece and was adjusted to be parallel to the visual axis of the microscope. When the visual axis and the virtual line were parallel, the displayed entry and target points were closest to each other [Figure 3c]. After cortical incision, the left lateral ventricle was reached as we proceeded to the white matter along the displayed virtual line, and the cerebral spinal fluid in the left ventricle was confirmed [Figure 3d]. It took us approximately 5 min from the cortical incision to complete this process. The surface of this mass was smooth and was identified as hemosiderin [Figure 3e]. Furthermore, this mass did not adhere to the ventricular wall, but instead was attached to the medial of the left lateral ventricle posterior wall. The mass was removed in one piece. Histopathological analysis identified this mass as xantogranuloma.

Postoperation

The patient had mild left-sided sensory depression and agraphia after surgery. Postoperative MRI confirmed the successful total removal of the mass and a tract which was in a straight line to the lesion [Figure 3f]. Gait of was improved following rehabilitation, and the patient was discharged home 2 weeks after the surgery. Agraphia was recovered by outpatient rehabilitation, and the median Karnofsky Performance Status was 90 at 3 months after the operation. No recurrence was observed in the images during that period. No post therapy is required for histopathology and we followed images.

DISCUSSION

Since the introduction of the first intraoperative frameless stereotactic navigation device by Roberts *et al.*, navigation

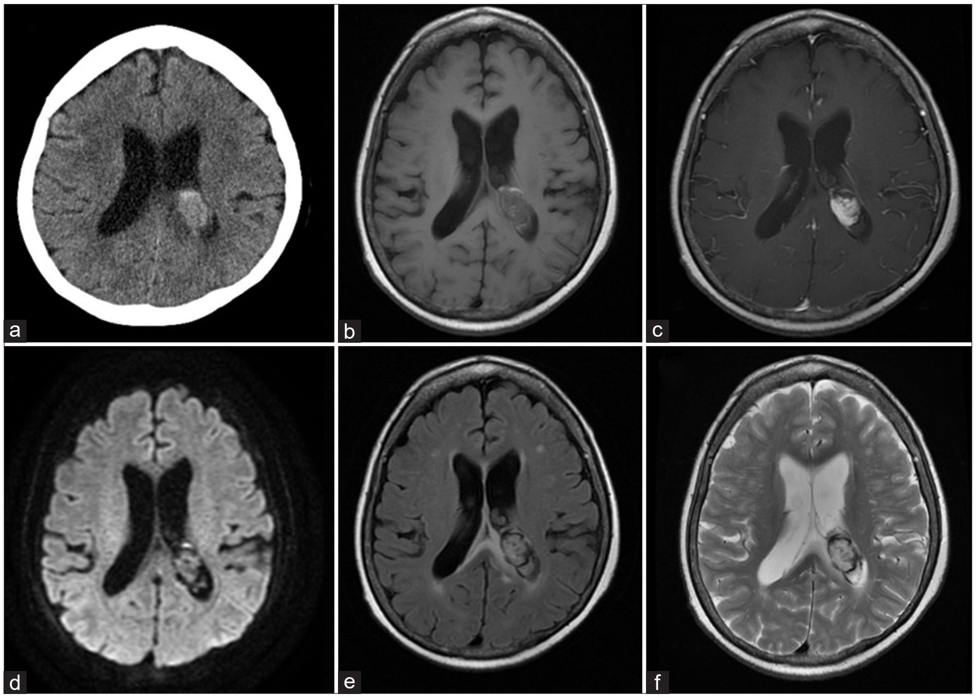

Figure 1: Preoperative computed tomography (CT) and magnetic resonance images. (a). CT images revealed a mass lesion with bleeding in the posterior horn of the left ventricle to the trigone part. (b) T1-weighted, (c) enhanced T1-weighted, (d) diffusion-weighted imaging, (e) fluid-attenuated inversion recovery, and (f) T2-weighted images.

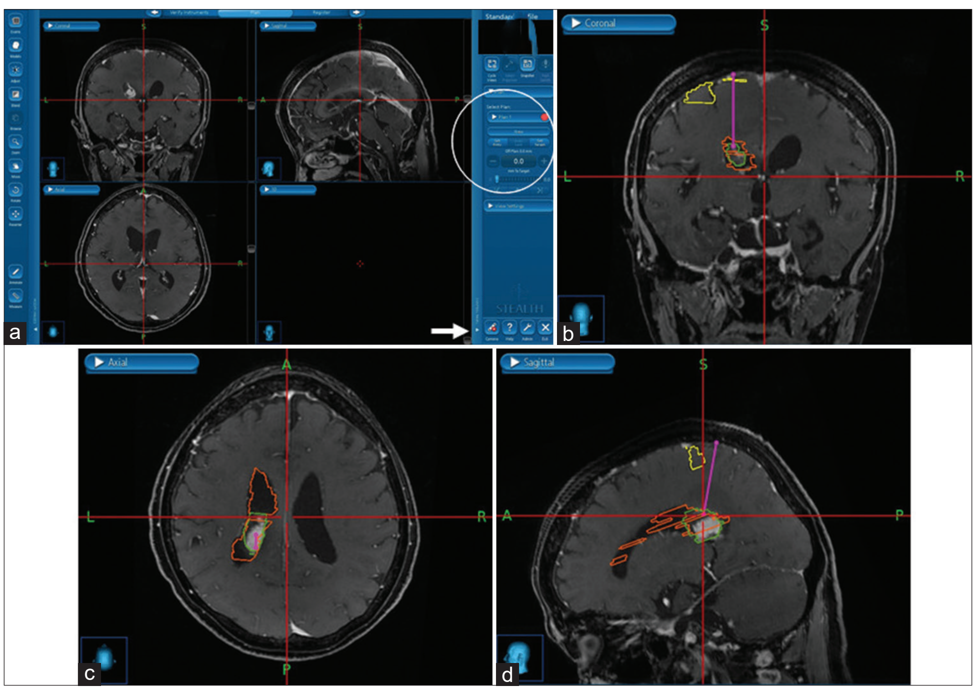

Figure 2: Surgical plan on the Stealth station. (a). When the tab displayed as plan on the right side of the screen was opened (arrow), items to set the entry and target were displayed (circle). (b-d). In this case, the superior parietal lobule was set as the entry, and the ventricular wall in contact with the mass lesion was set as the target. Consequently, a virtual line connecting these two points was displayed (pink line). The important structures during the operation were coloured to display the augmented reality image (post central gyrus was yellow; left ventricle was orange; mass lesion was green).

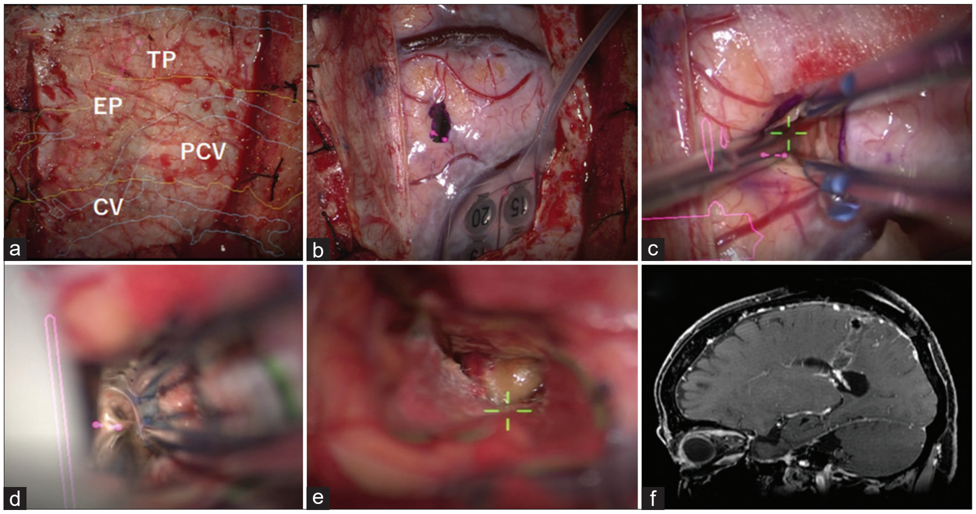

Figure 3: Intraoperative and postoperative images. (a) After craniotomy, structures were confirmed with augmented reality images from the surface of the dura matter (PCV [yellow]: Postcentral gyrus, CV [blue]: cortical vein, EP: Entry point, and TP [pink dots]: Target point). The planned entry point was marked on the dura matter. (b) After opening the dura matter, the post central gyrus was confirmed with sensory evoked potential. The point to enter was marked. (c) After corticotomy at the entry point, the approach route was made along the virtual line (Central visual axis of the microscope was green mark). (d) Cerebral spinal fluid was found when reaching the ventricle. (e) A mass lesion with hemosiderin deposition was found in the ventricle (Green marks was central visual axis of the microscopic). (f) Postoperative magnetic resonance images showed total removal of the mass, and a tract which was in a straight line to the lesion.

systems in neurosurgery have become indispensable devices due to their ability to increase accuracy and safety.[16] Over the past 30 years, the development of these system has enabled their application in complicated interventions, including surgical procedures of malignant tumors,[8,12] cerebrovascular disease,[1,10] and functional surgery.[2,6] One of the added functions is a system that can extract lesions and structures from the original MRI and CT images, create a related 3D model, and subsequently project this 3D model as an AR image on the microscope eyepiece. Some reports suggest the usefulness of this technology for education and surgical planning, limits to its application have also been proposed.[5,17] A technology for creating AR images using multiple cameras installed in the operating room has also been reported.[18] Satoh *et al*. reported that using AR images in neurosurgery could significantly aid in the accurate resection of both superficial and deep surgical tumors with either transcortical or interhemispheric approaches.[17]

A transcortical approach is a commonly used technique in neurosurgery for intraparenchymal and intraventricular lesions. However, this approach may lead to disorientation and can even cause unnecessary brain damage when the distance from the brain surface to the lesion is long. In this study, we determined that the superior parietal approach is the most suitable approach for dominant-sided trigone lesion without neurological symptoms of approximately 20–25 mm to preserve the white fibers associated with speech and visual pathways. The incidence of neurological symptoms caused by this approach for trigone lesions has not yet been reported in detail, and it has been proposed that speech and cognitive deficits, if any, are mild and transient.[3,4] In the present case, we obtained a good clinical course of treatment because the patient's agraphia improved approximately 3 months after the operation.

Although some techniques have been reported which avoid damage to the surrounding white matter,[14,15] few of them have the ability to approach the lesion.

Originally, the method shown in this case study uses the navigation program for a needle biopsy, where the tip of the navigation probe has been replaced by the surgeon's eye. While there are reports where conventional use of AR images as surgical support is performed for orientation purposes by visualizing existing and avoiding important structures, the novel approach presented in this study is based on an ideal line which can assist surgery by visualizing the surgical approach as a virtual. Even though our navigation system is not up-to-date, this line can be created at any point in a very simple way and in a very short time, enabling accurate surgical processes through real-time assessment of this virtual line. Compared to needle biopsy, this method has the advantage in some cases that it uses fewer tools and can remove the tumor bulk. Recently, there have been several reports using the ViewSite Brain Access System (VBAS®; Vycor Medical Inc.) for intraventricular lesions.[11] This virtual line method is as effective as an aid to secure a tract to insert this cylinder device.

However, there are some important issues to note. The most important thing is that brain shift causes the navigation to be less accurate. Brain movement is associated with excessive cerebrospinal fluid loss, administration of mannitol, and hernia due to preoperative brain swelling.[9] The surgical position is also an important factor that reduces navigation accuracy. However, it is possible to improve precision by fusing the preoperative CT image obtained in the operating room with the preoperative image taken in our institution after determining its position. The accuracy of the information on the brain surface can be improved by matching real-time information from the preoperative image and the surgical field, and subsequently confirming that information, such as central sulcus, during the operation using SEP and motor evoked potential. If a brain shift has occurred, it may be possible to perform a navigation palliative correction by refusing the structure with the AR image of the brain surface. Recently, a technique that can protect the white matter has been reported,[15] which is useful for shielding the white matter around the virtual line. Therefore, we intend to make use of this technique in the future studies.

CONCLUSION

Setting a virtual line as an AR image is a simple and accurate method that can effectively support the conventional transcortical approach.

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Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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