A new method of ultrasonic guidance of neuroendoscopic procedures

Technical note

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The authors present a newly designed device for ultrasonic guidance of neuroendoscopic procedures. It consists of a puncture adapter that attaches to a rigid endoscope having an outer diameter of 6 mm and is mounted on a small, bayonet-shaped ultrasound probe. This adapter directs the movement of the endoscope precisely within the ultrasonic field of view. The targeted region is identified by transdural insonation via an enlarged single burr-hole approach, and the endoscope is tracked in real time throughout its approach to the target. The procedure has been performed in 10 patients: endoscopic ventriculocystostomy in four cases; removal of a colloid cyst of the third ventricle in two cases; and intraventricular tumor biopsy, intraventricular tumor resection, third ventriculostomy, and removal of an intraventricular hematoma in one case each. The endoscope was depicted on ultrasonograms as a hyperechoic line without disturbing echoes and, consequently, the target (cyst, ventricle, or tumor) was safely identified in all but one case, in which intraventricular air hid a colloid cyst in the foramen of Monro.

The method presented by the authors proved to be very effective in the guidance and control of neuroendoscopic procedures. Combining this method with image guidance is recommended to define the entry point of the endoscope precisely.

KEY WORDS • intraoperative ultrasonography • ultrasound guidance • neuroendoscopic surgery • neuronavigation

Materials and Methods

The method originated in a recently published report of ultrasonic guidance during intracranial burr-hole procedures. A bayonet-shaped UP (EUP-NS32; Hitachi/Eco-scan Medical Corporation, Tokyo, Japan) with dimensions of 8 x 8 mm at its tip is used (Fig. 1 upper). The puncture adapter that is mounted on the UP has been modified to allow it to carry a 6-mm endoscope (MINOP system; Aesculap, Tuttlingen, Germany). The endoscope is directed via a guidance groove on the anterior aspect of the UP exactly to the ultrasonic field (Fig. 1 lower); thus, the entire path that the endoscope follows as it penetrates the brain toward the target point can be visualized on the screen. A standard 12-mm burr hole is created and enlarged another 8 mm laterally to enable transdural insonation. The targeted region is identified on the screen, a guideline is displayed, and the probe is tilted until the guideline crosses the target point. The endoscope is moved forward under real-time imaging control and can be placed in the desired position by the puncture adapter and a self-retaining retractor. The surrounding brain tissue remains under ultrasonic surveillance throughout the entire endoscopic procedure.

Abbreviations used in this paper: MR = magnetic resonance; UP = ultrasound probe.
Results

Ten patients underwent endoscopic surgery performed with ultrasonic guidance. The patients’ ages, sexes, and diagnoses are listed in Table 1. The endoscope was ultrasonographically identified as a hyperechoic line and could easily be detected as it followed its path to the targeted region in all cases. There were no disturbing echoes produced by the 6-mm rigid endoscope and, consequently, the target (cyst, ventricle, or tumor) was safely identified in all but one case, in which intraventricular air produced by previous external shunt placement allowed identification of the ventricles, but not of the colloid cyst occluding the foramen of Monro. Nevertheless, safe placement of the endoscope inside the lateral ventricle was achieved and ventricular irrigation cleared the ultrasonic image. Ultrasonography did not reveal any major hematomata of the surrounding brain tissue; this was confirmed using postoperative computerized tomography scanning.

Illustrative Cases

Case 6

A space-occupying cyst developed in a 12-year-old boy after he underwent resection, radiotherapy, and chemotherapy for a malignant rhabdoid tumor located in the right temporoparietal region with isolation of the temporal ventricle (Fig. 2 upper left). The endoscope was introduced under ultrasonic guidance, and a large fenestration was created between the ventricle and tumor cyst (Fig. 2 upper right and lower left). Figure 2 lower right shows the endoscopic view inside the temporal horn, which was obtained while the endoscope was located at the site displayed in Fig. 2 lower left.

Case 7

This 56-year-old woman was admitted to our hospital with signs of raised intracranial pressure. Magnetic resonance imaging revealed occlusive hydrocephalus caused by an intraventricular tumor (Fig. 3 upper left). The entry point to be used for the endoscope was defined by neuronavigation and the endoscope was introduced under ultrasonic guidance (Fig. 3 upper right and lower left). The tumor was easily visualized as it bulged into the ventricular cavity (arrow) and could be removed completely via the endoscope. Pathological examination revealed the tumor to be a dysembryoplastic neuroepithelial tumor.

Discussion

Guiding Systems in Neuroendoscopy

The first step in neuroendoscopic procedures is the correct placement of the endoscope in the targeted region, namely, a cyst or the ventricular system. In the past this was achieved by stereotactic methods, which were considered the standard procedure at the advent of modern neuroendoscopy.\textsuperscript{5,11,13,14} Stereotactic calculation of an accurate trajectory, especially when dealing with targets inside the
third ventricle, is of extreme importance to avoid damaging vaulted structures.\textsuperscript{10,11} At present frame-based stereotactic guidance of endoscopes is also used for biportal neuroendoscopy.\textsuperscript{15} In recent years frameless procedures have been developed based on image guidance that combined the flexibility of an unfixed, freely movable endoscope with the accuracy of stereotactic calculations.\textsuperscript{3,8,11,12,17,19,22,23,25} Neuro-navigation allows preoperative planning of entry and target points, selection of different trajectories, and the proper intraoperative placement of the preoperatively planned entry point and tracking of the endoscope.\textsuperscript{25}

**Endoscopic Guidance and Brain Shift**

The main disadvantage of both methods is that they rely on preoperatively acquired images and are thus susceptible to brain shift and movement of intracranial structures.\textsuperscript{7} This was considered to be of minor importance during neuroendoscopy guided by frameless neuronavigation, even if the endoscopic view did not allow the surgeon to define the correct fenestration site in cases of ventriculocystostomy.\textsuperscript{25} On the other hand, the rigid walls of ventricles or cysts are sometimes difficult to penetrate and a situation may occur in which image guidance depicts the correct intraventricular or intracystic position, although the endoscope only dents the wall. This would be especially disturbing during introduction of the operating sheath before insertion of the optical system, when the surgeon still has no endoscopic visual control.

Ultrasoundography as a real-time imaging modality may overcome such problems.

**Ultrasound-Guided Real-Time Imaging and Neuroendoscopy**

According to our experience with ultrasonic guidance of intracranial burr-hole procedures,\textsuperscript{27} we modified this method for guidance of rigid endoscopes. Until now ultrasonic guidance of endoscopic neurosurgery has been reported only as a consecutive method\textsuperscript{1} or in cases in which minicaliber endoscopes were used, applying a method similar to the one presented here.\textsuperscript{29} We found it necessary to construct a new puncture adapter fitting to the 6-mm outer diameter of our rigid endoscopes. The second problem we considered was the possibility that a 6-mm rod made of stainless steel would produce disturbing artifacts; interestingly, this was not the case. The endoscope was depicted as a well-defined small hyperechoic line without any surrounding attenuation of sound or disturbing echoes.

After having passed the puncture adapter, the MINOP endoscope can extend to a penetration depth of 80 mm, a critical depth for third ventriculostomy. The distance be-
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tween the typical precoronal entry point and the floor of the third ventricle is approximately 85 mm in the average patient (unpublished data); however, in patients with chronic hydrocephalus requiring third ventriculostomy, who are often macrocephalic the MINOP endoscope might be too short. This was not true in the case in which we performed third ventriculostomy. On the contrary, ultrasonic guidance was of utmost importance because a trabecular network made intraventricular orientation difficult and ultrasound safely guided the endoscope to and through a very enlarged foramen of Monro. Once the third ventricle was clearly identified, third ventriculostomy was performed easily. Alternatively, the UP can be removed once the endoscope has entered the ventricle and either good orientation is achieved or a longer endoscope can be used. On the other hand, it is a matter of debate whether image guidance is necessary at all to reach an enlarged ventricular system, although in our case it was demonstrated that reaching the ventricular system is not the only task of image guidance.

Another advantage of using this new device is permanent visual control of surrounding brain tissue along the trajectory of the endoscope as well as in front of the endoscope, which is not given by the endoscopic view or by neuronavigation. Ultrasonic imaging enlarges the endoscopic view by “looking through the parenchyma” as Resch, et al., stated in their report on endoneurosonography.

Our method cannot be used to define the exact position of the entry point. Therefore, we combined neuronavigation and ultrasonic guidance in Cases 7, 8, and 9: preoperative planning and intraoperative localization of the entry point are performed with the aid of neuronavigation; the procedure itself is guided by ultrasonography, thus adding real-time information that can be used to detect possible brain shift (especially when dealing with fenestration of large cystic lesions), to check the position of the endoscope, and to survey surrounding brain tissue.

Conclusions

A simple but safe and reliable method of ultrasound-based neuroendoscopic guidance is presented that may increase the safety of these procedures by providing real-time visual control of the path that the endoscope follows toward the target. Combining this method with standard image guidance to define the endoscope entry point precisely is recommended, but wide experience with this method is still lacking.
Disclaimer

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References


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