Neuroendoscopy via an Extremely Narrow Foramen of Monro: A Case Report

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Herein, safe and reliable neuroendoscopic biopsy via an extremely narrow foramen of Monro (ENFM) for a non-hydrocephalic patient with hypothalamic and pineal region tumors was successfully applied. A 17-year-old boy presented with hypothalamic manifestations attributed to hypothalamic and pineal region tumors. Small ventricles were seen. Intraoperatively, to advance different diameter steerable fiberscopes via ENFM, the third ventricle was flushed to induce a moment increase in the intraventricular pressure with subsequent dilatation of FM. Postoperative course was uneventful. Histopathological studies revealed a yolk sac tumor. Adjuvant therapy was applied. Follow-up neuroimaging disclosed marvellous improvement of the condition. His symptoms gradually improved.

Keywords: endoscopic biopsy; foramen of Monro; pineal tumor; small ventricle; fiberscope

Introduction

Neuroendoscopy is widely accepted as the first choice for biopsy of pediatric intra- or periventricular tumors.[1] In many cases, histological confirmation alone is adequate and lead to subsequent chemo- or radiotherapy.[2] The combination of neuroendoscopy and neuronavigation improves the accuracy of endoscopic approach and further minimizes brain trauma,[3] thus, ventricular dilatation is no longer an indispensable prerequisite.[1] However, when the foramen of Monro (FM) is narrow the procedure will be more challenging. Herein, the authors presented surgical tips to perform a minimally invasive approach to the hypothalamic region tumor via an extremely narrow FM (ENFM), and obtain an accurate histolopathological diagnosis for promising excellent adjuvant therapeutic outcome.

Case Report

History and examination

A 17-year-old boy suffered from hyperphagia with subsequent increased body weight, as he gained 40 kilograms in 8 months. The detailed neuropsychological assessment revealed no deficits, apart from scattered focal visual field defects. General physical examination disclosed morbid

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obesity "*body mass index (BMI) = 33.95*". Preoperative hormonal assay showed reduction of the luteinizing hormone, follicle-stimulating hormone and testosterone levels. Repeated tumor markers' assessment disclosed gradual marked elevation of the alpha-fetoprotein (AFP) (1999.3 ng/ml) and normal human chorionic gonadotropin levels. Preoperative magnetic resonance images (MRIs) revealed hypothalamic and pineal region tumors. Additionally, enhanced nodules were noticed within the left lateral and fourth ventricles (Fig. 1A). Small ventricles (*Frontal and occipital horn ratio (FOR) [19] > 0.37*) was seen (Fig. 1B). Fluid-attenuated inversion recovery (FLAIR) MRI disclosed marked bilateral forniceal edema, with subsequent obvious narrowing of the FM. The right FM was 1.35 mm, and the left FM was 2.02 mm in diameter. Extremely narrow FM were suspected (Fig. 1C, D). A screening MRI of the spine was negative for tumor.

Operation

Under general anesthesia, the patient was positioned supine with the head elevated and flexed to minimize cerebrospinal fluid (CSF) outflow. As an enhanced nodule was located in the left lateral ventricle, and the left FM was relatively wider than the right one (Fig. 1D), the neuroendoscopic approach was performed via left precoronal burr hole. Under neuronavigation guidance, a strait trajectory was designed *(to avoid undue torque on the cortex or structures around the FM)* from the skull bone, passing through the ENFM to the tumor, and the burr hole was tailored accordingly (*1 cm anterior to the coronal suture and over the midpupillary line*). After dural incision and arachnoid coagulation, the lateral ventricle was approached, with ventricular tap needle, under navigational guidance (*BrainLAB, Feldkirchen, Germany*).[4] Only the location of the entry point and the approach trajectory were determined with neuronavigation while the procedure itself was performed under endoscopic visual control. Once the ventricle was cannulated, CSF pressure was measured and samples were sent for further analysis. Using the same trajectory, an endoscopic transparent sheath (*Neuroport® mini size; Olympus Corp., Tokyo, Japan*) was introduced. First, steerable fiberscope 2.5 mm (*MACHIDA SEISAKUSYO, MACHIDA, INC, Tokyo, Japan*) was advanced towards the lateral ventricle. The ventricle was like a gorge (Fig. 2E), careful dripping irrigation was performed to ensure patency of the ingress route, using the controllable endoscopic channel which was connected to a reservoir of the warm artificial CSF solution. Endoscopic inspection of the lateral
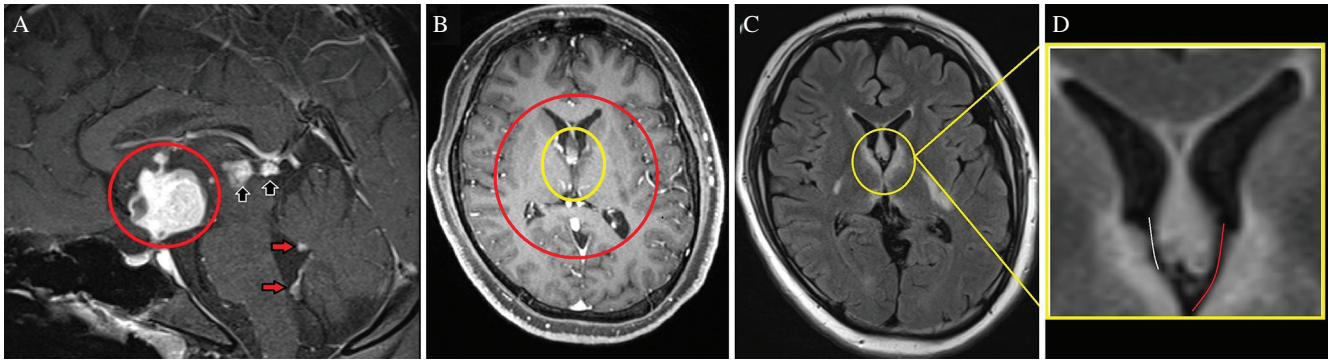
Fig. 1 Preoperative MRI; (A) Post-contrasted sagittal MRI showing the suprasellar hypothalamic tumor (red circle) measuring 29 mm and pineal region tumor (black arrows) measuring 9 mm in the maximum diameters. Fourth ventricular nodules (red arrows), indicating dissemination, are seen. (B) Post-contrasted axial MRI showing no hydrocephalus (red circle), notice the extremely narrow foramina of Monro and the slit-like third ventricle (yellow circle). (C) FLAIR-MRI axial view, showing edema of the fornix with subsequent narrowing of the foramina of Monro "*left = 2.02 mm, right = 1.35 mm in diameters*" (yellow circle). (D) Zoom in (400%) at the level of the extremely narrow foramina of Monro, the right route (white line) is narrower than the left one (red line).

ventricle could not identify any abnormal lesions. Major landmarks (*choroid plexus passing through an ENFM to the third ventricle, and at its lower margin the point where the thalamostriate vein unites with the septal vein*) were identified (Fig. 2A). Here, close to FM, the flush technique was carried-out with careful monitoring of the heart rate. In this flush technique, a direct bolus of 10 ml warm artificial CSF solution was flushed over 4 seconds, via the endoscopic channel, to induce a moment increase in the intra-third-ventricular pressure (Fig. 3) and subsequent dilatation of the FM (Fig. 2B). This slow injection accomplished a safe gradual dilatation of the FM.[1] In synchronization with this real-time dilatation of the FM, the fiberscope was advanced to the third ventricle without traumatizing the fornix, choroid plexus or related veins (Fig. 3). Although some landmarks of the third ventricle were not distinguishable, a whitish hypothalamic tumor was clearly visualized (Fig. 2C). The 2.5 mm fiberscope was exchanged with 3.7 mm fiberscope (Fig. 2D) (*Karl Storz, Tuttlingen, Germany*) and an initial biopsy was taken for frozen section, followed by 5.0 mm videoscope (Fig. 2E–I) (*Olympus Corp., Tokyo, Japan*) in order to gain accurate anatomical orientation and to obtain reliable biopsies. While keeping a distance from surrounding structures, specimens were obtained from the hypothalamic lesion. As soon as the biopsy was completed, the ventricles were copiously rinsed. Local bleeding was well-controlled using irrigation. Frozen section revealed a germ cell tumor. After confirmation of hemostasis, the wound was closed without ventricular drainage. In this procedure three main surgical tips were done: 1- neuronavigation-guided ventricular tap, 2- different diameters fiberscopes for inspection and manipulation, and 3- "flush technique" to pass safely through ENFM.

Postoperative course

No evidence of surgical complications (Fig. 4A). Histopathological studies revealed a yolk sac tumor (Fig. 5). Chemotherapy (**ICE: I**fosfamide-**C**arboplatin-**E**toposide × 4 cycles) followed by radiotherapy (54 Gy/30 fractions) were

administered. Postoperative course was uneventful. His symptoms and the visual field gradually improved.

Follow-up

MRI 3- and 6-month-postoperatively disclosed marvelous improvement of the condition and almost disappearance of the intracranial lesions (Fig. 4B). FLAIR-MRI showed resolution of the forniceal edema and normalization of the FM (Fig. 4C). His developed panhypopituitarism, which attributed to the adjuvant therapy, is well controlled by hormonal replacements.

Discussion

Neuroendoscopic biopsy

It is most strongly indicated for tumors for which postsurgical adjuvant treatment is effective (*as our case*).[5,6] Because the treatment regimens for pineal region tumors vary greatly and the risks of a full resection are potentially high, an initial accurate minimally invasive tissue diagnosis is paramount.[7] Biopsy may permit differentiation of cases requiring a microsurgical approach from those to be treated with adjuvant therapy alone,[5] and provide meaningful pathological data for the majority of patients.[8–13] Even, in benign or redioresistant tumors, endoscopic biopsy would lead to more appropriate management.[2,10,14]

Pediatric suprasellar tumors form a unique category in histology, incidence, and treatment,[15] also, present a real surgical challenge to the neurosurgeon.[7,9,16] This group of tumors do not always require aggressive surgical intervention.[2] A substantial number of neoplasms can be successfully managed without surgical intervention.[17,18] Furthermore, in cases of malignant tumors, even extensive surgical resection does not eliminate the need for subsequent adjuvant therapy.[19,20] Also, within each tumor there is the potential for heterogeneity, thus, an accurate diagnosis is pivotal in deciding on a formal treatment strategy.[8,10,21]

Advantages of steerable fiberscope

Movements of only the distal portion of the endoscope allow the surgeon to avoid undue torque on the cortex or
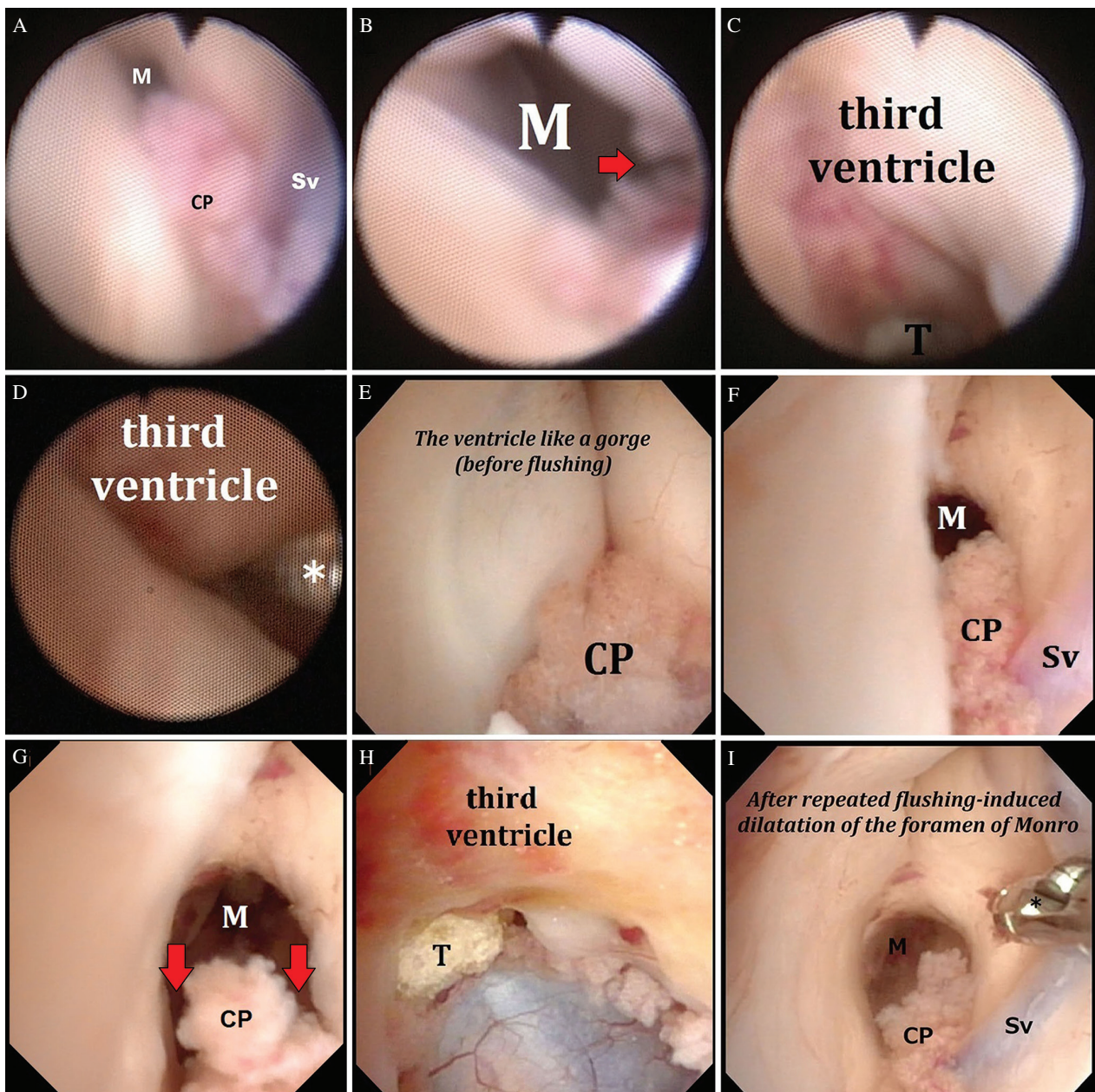
Fig. 2 Neuroendoscopic video-captured images; (A, B, C) A 2.5 mm fiberscope during careful endoscopic inspection. The major anatomical landmarks were identified: "*the choroid plexus (CP) passing through an extremely narrow FM (M) to the third ventricle, and at its lower margin the point where the thalamostriate vein unites with the septal vein (Sv)*". The whitish hypothalamic tumor (T) was visualized inside the 3rd ventricle. Notice the (image B) flushing-induced dilatation of the FM. (D) A 3.7 mm fiberscope was used to get tumor biopsies. (E–I) A 5.0 mm videoscope was introduced in order to gain accurate pertinent anatomical orientation and to obtain reliable biopsies. Before flushing the ventricle was like a gorge (E), however, during flushing the landmarks became gradually obvious (F). Just before passing through the FM to the third-ventricle: a closer position of the fiberscopes showing the efficacy of the flush technique (B and G). Notice the degree of FM dilatation and its' increased diameter *(a space was created around the CP "red arrows")*. Additionally, the high resolution images obtained by the 5.0 mm videoscope ruled-out any forniceal injury (I). CP: *choroid plexus,* M: *foramen of Monro,* Sv: *Septal vein,* T: *tumor,* *: *tumor forceps.*

structures around the FM, including the fornix, thalamus, and deep veins.[22]

Neuroendoscopy in small ventricles

Small ventricles may not be served as a contraindication to endoscopic tumor biopsy.[1,12,21–27] However, without neuro-navigation, the failure rate to reach the correct path to the lateral and third ventricles is high if the ventricular size is extremely small.[15]

Neuroendoscopic management of ENFM

Patients without hydrocephalus are expected to all have a normal to small FM with a vulnerability to unilateral forniceal scratch, moreover, when forniceal edema is superimposed
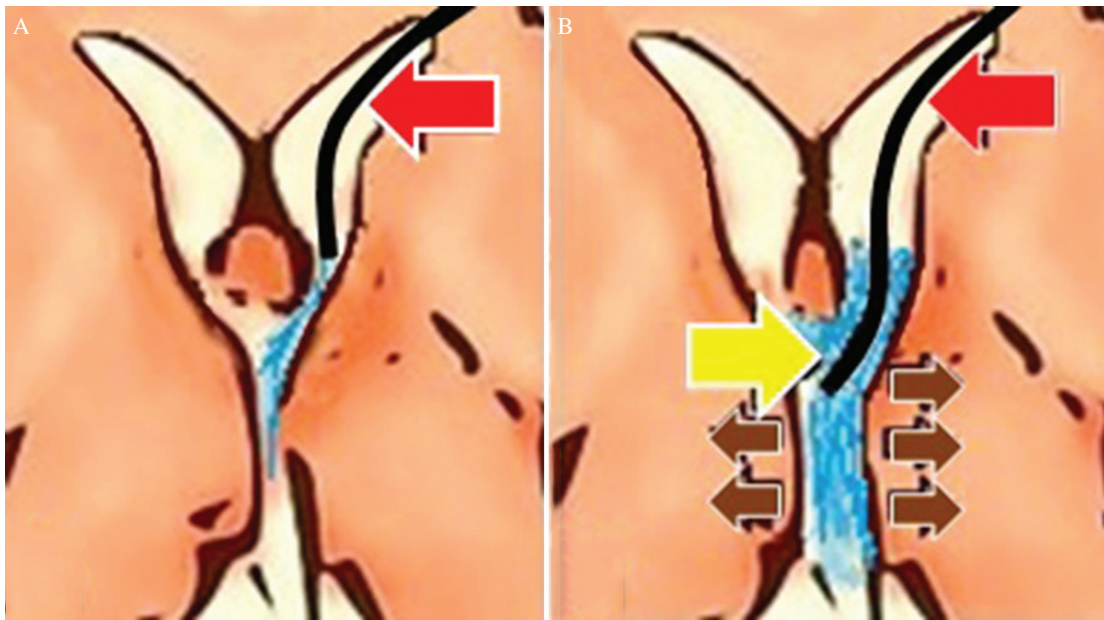
Fig. 3 Schematic drawing showing the flush technique, (A) A direct bolus of 10-ml warm artificial CSF solution was flushed gradually, via the endoscopic channel (red arrow). (B) A moment increase in the intra-third-ventricular pressure (brown arrows) and subsequent dilatation of the FM were achived. Simultaneously, the fiberscope (red arrow) was safely advanced to the third ventricle (yellow arrow). The third ventricular size became comparable.
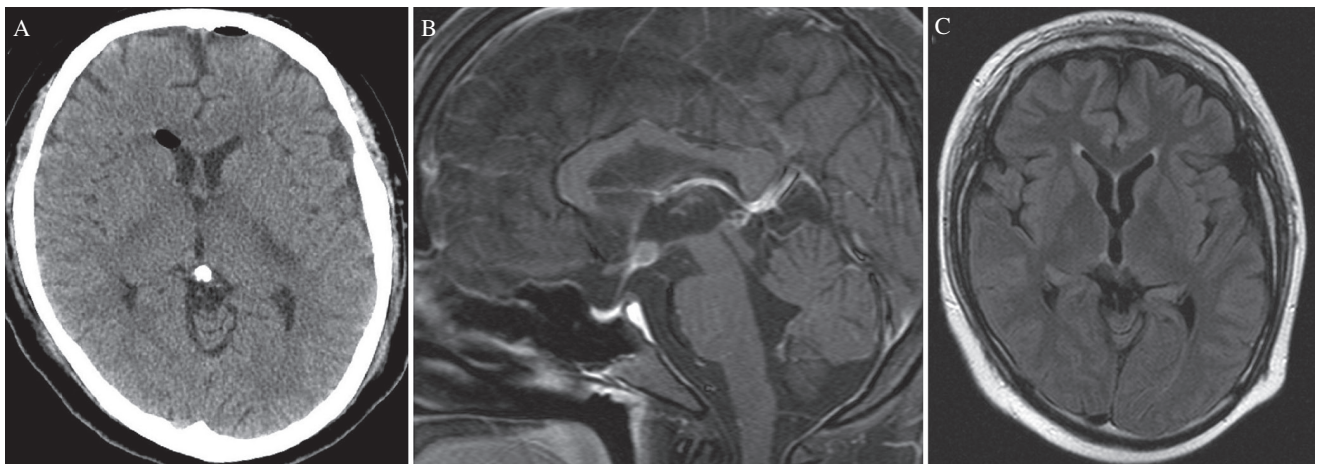

Fig. 4 Postoperative and follow-up neuroimaging; (A) CT on postoperative day 1 ruled out surgery-related complications. (B) Follow-up post-contrasted sagittal MRI 3 months postoperatively (*effect of adjuvant therapy*) disclosed marvelous improvement of the condition and almost disappearance of the intracranial lesions C: Follow-up FLAIR-MRI axial view 6 months postoperatively, showing resolution of the forniceal edema and normalization of the foramina of Monro (left = 4.98 mm, right = 4.25 mm in diameters).

(as in our case), FM became much smaller "*extremely narrow*" and the fornix come to be at a critical risk for injury.

In this report, an ENFM was highly suspected, and it was considered amendable by adequate meticulous flushing during small-diameter-steerable neuroendoscopy.

In previous important neuroendoscopic studies included patients with small ventricles,[12,26,27] there was no objective definition or measurement of the ventricular size. In addition, patients were categorized into the small-ventricle and ventriculomegaly groups based on FOR in other studies.[24,28,29] In turn, up to now, the size of the FM was not clearly described.

It seems necessary to record the diameter of the FM for each patient enrolled in neuroendoscopy. This might not only serve the surgical outcome by selecting the proper endoscope or the future of neuroendoscopy by further development, but also provide a pertinent anatomical reference.

Flushing technique and conventional irrigation method

Conventional irrigation method is considered effective to insufflate small ventricles. However, during this continuous irrigation, a great attention to the patient's hemodynamic status is necessary to exclude relative bradycardia secondary
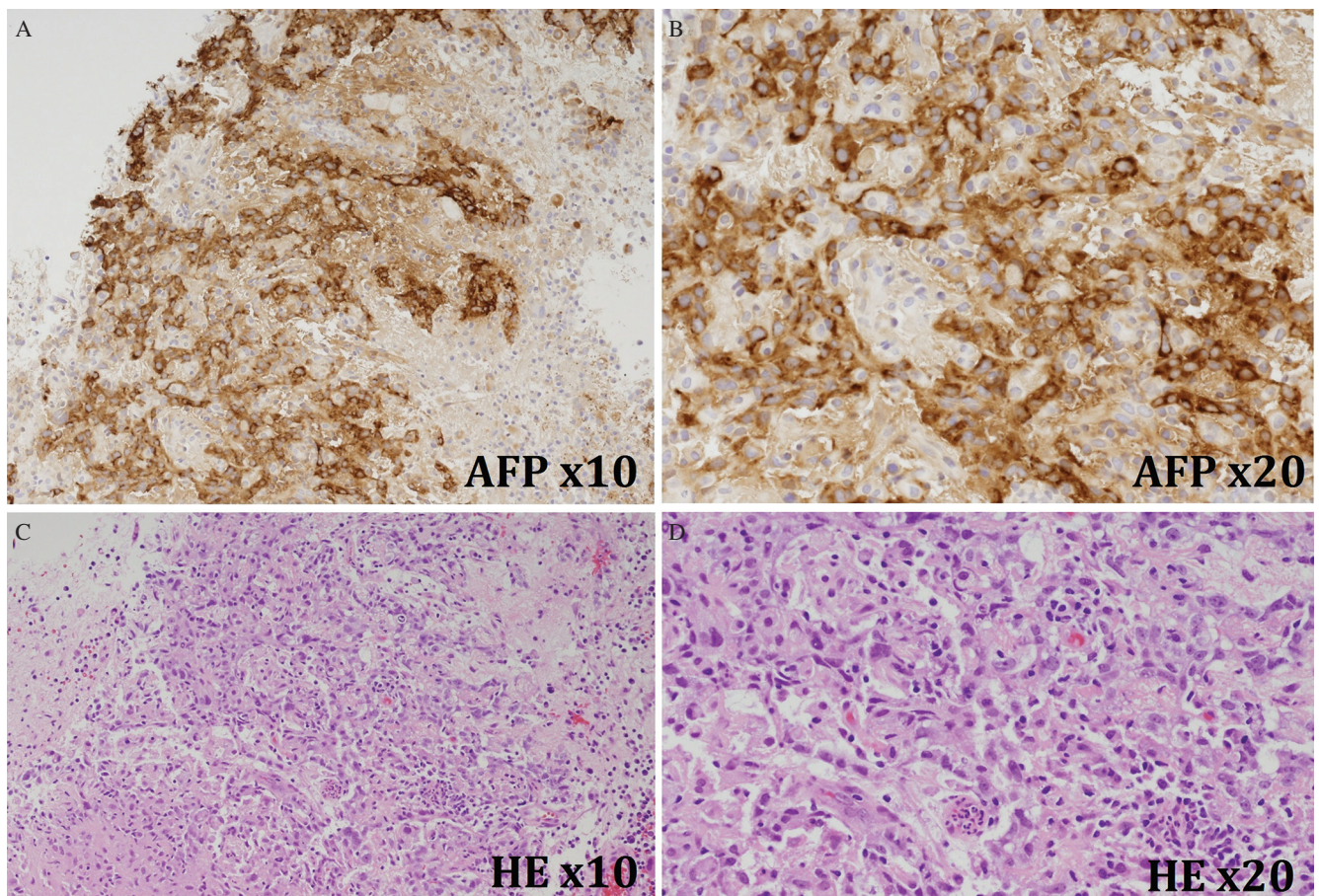
Fig. 5 Immunohistochemical and histopathological studies; (A) (AFP × 10) and (B) (AFP × 20): Immunohistochemical staining for α -fetoprotein (AFP), tumor cells showed strong cytoplasmic staining. (C) (HE × 10) and (D) (HE × 20): Photomicrograph of histopathological sections with hematoxylin and eosin (HE) staining: small slit-like spaces lined by atypical tumor cells. Tumor cells were pleomorphic, had abundant eosinophilic or clear cytoplasm and marked nucleoli which were arranged in nest or reticular pattern. Papillary growth pattern and mitotic figures could be found.

to raised intracranial pressure (ICP).[1] In this method, the intra-lateral-ventricular pressure should be increased to ensure the ingress route while keeping the size of FM (*risk for forniceal injury*) unchanged. As, *firstly,* the exact threshold of the fluid needed to induce safe ventricular dilatation is not determined (increased ICP cannot be predicted), *second,* the increased ICP will be realized only once bradycardia occurs and, *third,* the structures around the FM still at risk, these are considered three major shortcomings in conventional method for small ventricular endoscopy.

The novel of "flush technique" exists in inducing a moment increase in the intra-third-ventricular pressure (Fig. 3) to amend the ENFM, before navigating the endoscope, for the safety of the structures around the FM. Thus, a nonviolent neuroendoscopic biopsy via an ENFM could be achieved without injuring the fornix. We successfully obtained this merit (Fig. 2I). Additionally, this technique maintains an ICP that cannot exceed the pressure of a fluid column equal to the length of the endoscope, provided that a constant purge is used.

The aim of this study is not to compare the conventional irrigation method versus our introduced flush technique. However, we believe that the result of our patient may provide a

perspective. Finally, we are aware that a single presented case with hypothalamic lesion is a limitation for our study. Further researches incorporating patients with ENFM and other intra-third-ventricular (*posteriorly "pineal" or anteriorly-located*) tumors are required to validate our results and make more solid conclusions, as injury to the fornix is more likely to occur among this group.

Conclusion

We first introduce a flushing technique by which a safe neuroendoscopic biopsy can be successfully applied even via an ENFM for non-hydrocephalic patients with intraventricular and pineal region tumors. It seems necessary to record the diameter of the FM for each patient enrolled in neuroendoscopy. This pertinent anatomical reference might serve the surgical outcome by selecting the proper technique and enhance the future of neuroendoscopy.

Conflicts of Interest Disclosure

The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices in the article. All authors who are members of the Japan Neurosurgical Society (JNS) have registered online Self-reporting Conflict

Disclosure Statement Forms through the website for JNS members.

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