**Application of endoscopic ultrasonography to intraventricular lesions**

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**Abstract**

Background: Anatomical landmarks such as choroid plexus and foramen of Monro are very important to undergo intraventricular surgery safely and effectually. These landmarks would be unclear in cases with a huge cyst or repeat surgery. We report the usability and precautions to apply a bronchoscope with an ultrasonic convex probe to intraventricular surgery.

Methods: Two patients diagnosed with obstructive hydrocephalus, one with a large cyst and the other with recurrent craniopharyngioma in the third ventricle, were applied to the EBUS system.

Results: In both patients, the EBUS system was applied safely and lesions beyond the wall of ventricles or the cyst were visible. Color Doppler ultrasonography detected choroid plexus and internal cerebral veins. Furthermore we performed real-time ultrasound- guided cyst puncture safely on the case with a large cyst. The most important precaution is that the curved portion of the EBUS system is too long to be bent within cerebral ventricles.

Conclusion: The new EBUS system with an ultrasonic convex probe is a novel and effectual device to perform intraventricular surgery.

**Key words**: intraventricular lesion, flexible endoscopy, endoscopic ultrasonography, real-time ultrasonic guidance

## Introduction

In the Department of gastroenterological and respiratory medicine, ultrasound endoscope has developed and enhanced safety and efficiency. Endobronchial ultrasound (EBUS)-transbronchial needle aspiration (TBNA) in the diagnosis of mediastinal masses performed better in terms of diagnostic yield compared with conventional TBNA [1, 5-9]. In neurosurgical operation, Ishikawa et al. reported endonasal ultrasonography-assisted neuroendoscopic transsphenoidal surgery with the EBUS system. Intracranial arteries, residual tumor and lateral ventricles were clearly recognized [3]. EBUS system with a new convex probe (EBUS system: EB-530US; Fujifilm, Tokyo, Japan or BF-UC260F-OL8; Olympus, Tokyo, Japan) is small enough to apply to intraventricular surgery (Fig1). We applied the EBUS system to observe deep brain structures to two cases of obstructive hydrocephalus; one with a large cyst, and the other with recurrent craniopharyngioma of the third ventricle, due to the difficulties in confirming surgical landmarks such as choroid plexus and foramen of Monro (FOM). We report the efficacy and precaution of the EBUS system when applied to intraventricular surgery.

## Materials and methods

*Specifications of the endoscope for EBUS –TBNA (EB-530US)*

The EBUS system is larger than the conventional neuroendoscope (VISERA ventricular video scope

OLYMPUS VEF TYPE V, Olympus, Tokyo, Japan: VEF) (Table). The maximal diameter of the EBUS system is 6.7mm. The curved portion and the working length of the EBUS system are 73mm and 610mm respectively, more than twice of the VEF (Fig. 1A and B). The forceps channel diameter of the EBUS is 2.0mm (Fig.1C, white arrow), equal to the VEF but the direction of the channel exit is at 30° to the insertion direction (Fig. 1D). The length from the lens (Fig. 1D, black arrow) to the tip is 19mm. The camera of the EBUS system has 120°field of view with 10°forward oblique view. The convex transducer with a frequency of 5-12 MHz scans parallel to the insertion direction and has 65°scan angle combining with a dedicated ultrasound scanner (SU-8000, Fujifilm). Ultrasonic images can be caught by contacting the probe directly or through the intermediary of a balloon put on the tip (Fig. 1C, black arrow head) in EBUS-TBNA, though there is no need to contact the probe in cerebral ventricles filled with cerebral fluid. The maximal viewable depth is about 120mm.

*Patients*

The EBUS system was applied to two patients diagnosed with obstructive hydrocephalus, one with a large cyst and the other with a recurrent craniopharyngioma in the third ventricle. The institutional review boards at Hokkaido University Hospital had approved the clinical study of the EBUS system to the intraventricular surgery. Informed consents had been given from the patients and/or their family.

## Results

*Case1*

A 29-week-old fetus was found with enlarged cerebral ventricles and referred in the department of obstetrics of our hospital. Fetal magnetic resonance imaging (MRI) revealed a subacute-phase hemorrhage in the right lateral cerebral ventricle (LCV) (Fig. 2A). The fetus was delivered by Cesarean section at 37-weekgestational age. She had grown normally until 7 months old despite the ventricular dilatation. An MRI showed expanded LCVs and a cystic lesion in the right LCV (Fig 2B). At 1 year and 10 months old, she showed mental and motor development delay, babbling and pulling herself up to standing. An MRI showed the cyst and both LCVs had expanded more than the past year. The cyst forcefully compressed the septum pellucidum and caused obstructive hydrocephalus (Fig. 2C).

At two years old, we performed an endoscopic surgery to relieve obstructive hydrocephalus under general anesthesia in the supine position. A skin incision and a small craniotomy were performed centering 3.5 cm lateral to the midline and slightly anterior to the coronal suture. After opening the dura and coagulating the brain cortex, we placed a transparent sheath of 10 mm diameter (Neuroport; Olympus Corp.) into the frontal horn of LCV under normal ultrasonic guidance and then inserted the EBUS system (EB-530US, Fujifilm Corporation, Japan) through the sheath. We could not see anatomical landmarks such as the FOM and choroid plexus because of the compressed septum pellucidum by the cyst. (Fig. 3B) We used ultrasonography, and then could see the inside of the cyst beyond the septum pellucidum (Fig. 3C and 3D). We converted endoscope from the EBUS system to a rigid one, opened the septum, and the wall of the cyst reliably. Next, we relieved the isolated posterior and inferior horn of the right LCV. Application of the EBUS system made it possible to find out the right direction to the posterior horn (Fig. 3F and 3G) and the posterior cyst wall was punctured under real-time ultrasonic guidance without any complications (Fig. 3G). We confirmed the relief of the obstructive hydrocephalus by observation of the left FOM and to-and-fro motion of the septum and the cyst wall of the right posterior horn (Supplemental Video. Video that demonstrates the plan and the actual surgical procedure of the Case 1, 2 minutes and 16 seconds, 219MB.). Postoperative MRI showed flow-voids around the opened walls and relief of the obstructive hydrocephalus (Fig. 2D).

The patient became ambulatory and used single-word speech at 2 years and 10 months old. An MRI showed the cyst walls remained opened.

*Case2*

An 18-year-old boy underwent surgery of purely the third ventricle craniopharyngioma (Fig. 4A) via a transcortical transforaminal approach. Five months after the surgery, an MRI revealed a recurrent tumor as a cystic lesion within the third ventricle. Ten months after the surgery, not only the cyst but also a nodule became enlarged (Fig. 4B). The obstructive hydrocephalus also developed and we planned an endoscopic cyst puncture, resection of the nodule and placing a ventriculo-peritoneal shunt.

A skin incision and craniotomy in the right frontal were made in the same way as the last operation. The right FOM was not clear by adhesion (Fig. 5B), and barely identified by choroid plexus. Using ultrasonography, we confirmed the tumor nodule and the cyst (Fig. 5C). Color Doppler ultrasonography could identify choroid plexus and the right internal cerebral vein near the adhesion (Fig. 5D). We opened the adhesion of FOM and the tumor cyst and resected the tumor nodule (Fig. 5E) with a rigid endoscope. Finally, ventriculo-peritoneal shunt was placed.

A postoperative MRI showed the shrunken tumor cyst (Fig. 4C) and the patient received proton therapy to the remnant.

**Discussion**

Nowadays endoscopic surgery of intraventricular, paraventricular lesions and obstructive hydrocephalus are routinely performed. The safety and validity of endoscopic intraventricular surgery have been established in appropriate cases maintaining anatomical landmarks like choroid plexus, foramen of Monro and intraventricle vessels [2, 4]. In some cases with large cyst or repeated surgery, it is difficult to confirm such landmarks. The EBUS system with a new convex probe allowed visualization of the deep brain structures beyond the cyst wall and made it possible to perform real-time ultrasound guided punctures of the cyst wall.

To apply the EBUS system to intraventricular surgery safely, the following precautions need to be taken into account due to the various specifications of the EBUS system (Table and Fig.1) from the conventional flexible neuroendoscope. The head of the EBUS system, 19mm from the lens to the tip (Fig. 1C), makes it difficult to go close and observe objects. The greatest diameter of the EBUS system is larger than the VEF. This is the reason we decided to place a 10 mm diameter sheath. Another key difference is each length. The EBUS system is so long (Fig. 1A) that conventional devices such as a coagulator like ME2 monopolar electrode (Codman & Shurtleff, Johnson & Johnson, Raynham, MA) cannot be used. Furthermore, the curved portion of the EBUS system is also too long to be bent within ventricles (Fig. 1B). We kept the EBUS system almost straight during operations (Fig.3A, 3E and 5A). Shortening the EBUS system and its curved portion would expand the application of an endoscope with ultrasonic probe for intraventricular surgery. The shortened EBUS system could not only be handled easily in cerebral ventricles, but also would allow the conventional neuroendoscope devices such as ME2.

**Conclusion**

Through the two cases of obstructive hydrocephalus with intraventricle lesions, the value of endoscopic ultrasonography to capture the image of deep structures and the precautions for the EBUS system usage within the cerebral ventricles were demonstrated. It is possible and valuable to adopt the EBUS system in appropriate cases with special attention as discussed above. As far as we know, this is the first report of the application of endoscopic ultrasonography to intraventricular lesions.

## Conflict of interest

All authors certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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**Figure legends**

Fig.1

A: Active length of the bronchoscope with ultrasonic convex probe (b: EBUS system; model EB-530US, Fujifilm) is 320mm longer than that of the conventional flexible neuroendoscope (a: VEF-V, Olympus) (a). B: Photograph of the endoscopes in flexion. (b) Bend section of the EBUS system is 43mm longer than that of the conventional neuroendoscope. C and D: Head of the EBUS system. There is a lens of the camera (A; black arrow) between two lights, a forceps channel opening at the distal of the lens (C, white arrow) and a nub (B; black arrow head) at the tip attached to a balloon with saline solution for obtaining ultrasonic images during bronchoscopy.

Fig.2 MR images of the Case 1

A: Fetal MRI revealed subacute-phase hemorrhage in the right lateral cerebral ventricle (LCV). B and C: MRI showed a growing cyst in the right LCV at 10 months old (B) and 1 year and 10 months old (C). D: Postoperative MRI showed the shrunken cyst, and flow-voids of the septum pellucidum and the posterior cyst wall.

Fig.3 Intraoperative image of the Case 1

A: The white arrow in the MRI indicates the position and the direction of the endoscope in Fig. B, C and D. B: A view of the left LCV before septostomy. All anatomical structures that could be seen were on the ventricle wall and a wall that might be the septum pellucidum compressed by the cyst. C and D: The EBUS system was inserted in the left LCV and attached on the wall believed to be the septum (C) and revealed a large cavity of the cyst beyond the wall (D). E: The white arrow in the MRI indicates the position and the direction of the endoscope in Fig. F. F: EBUS system in the cavity of the cyst visualized the posterior-horn of the right LCV beyond the posterior cyst wall. G: Images of an endoscope and an ultrasonography in the course of puncture to the posterior cyst wall under real-time ultrasonic guidance with the EBUS system.

Fig.4 Gadolinium-enhanced MR images of the Case2.

A: Pretreatment MRI showed a purely third ventricle craniopharyingioma. B: Ten months after the operation, an MRI revealed the tumor recurrence as a cyst and a nodule in the third ventricle. The tumor cyst obstructed both foramens of Monro (FOM) and caused hydrocephalus. C: MRI after endoscopic fenestration of the tumor cyst and removal of the tumor nodule.

Fig.5 Intraoperative image of the Case 2.

A: The white arrow in the MRI indicates the position and direction of the endoscope in Fig. B and C. B: A view of the right LCV showed the FOM covered by adhesion (white arrow). C: Application of the EBUS system visualized the tumor nodule (arrows) beyond the adhesion by ultrasonography. D: Color Doppler ultrasonography could identify choroid plexus (arrow heads) and the right internal cerebral vein (white arrow). There was no vascular structure under the adhesion. E: There was the tumor nodule on the third ventricle floor as observed by the ultrasonography.

Table Specifications of each endoscope

| Specifications | VEF TYPE V | EB-530US |
|---|---|---|
| |  |  |
| Distal end diameter | 5.0mm | 6.7mm |
| **Forceps channel diameter** | **2.0mm** | **2.0mm** |
| Curved portion length | 30mm | 73mm |
| **Working length** | **290mm** | **610mm** |

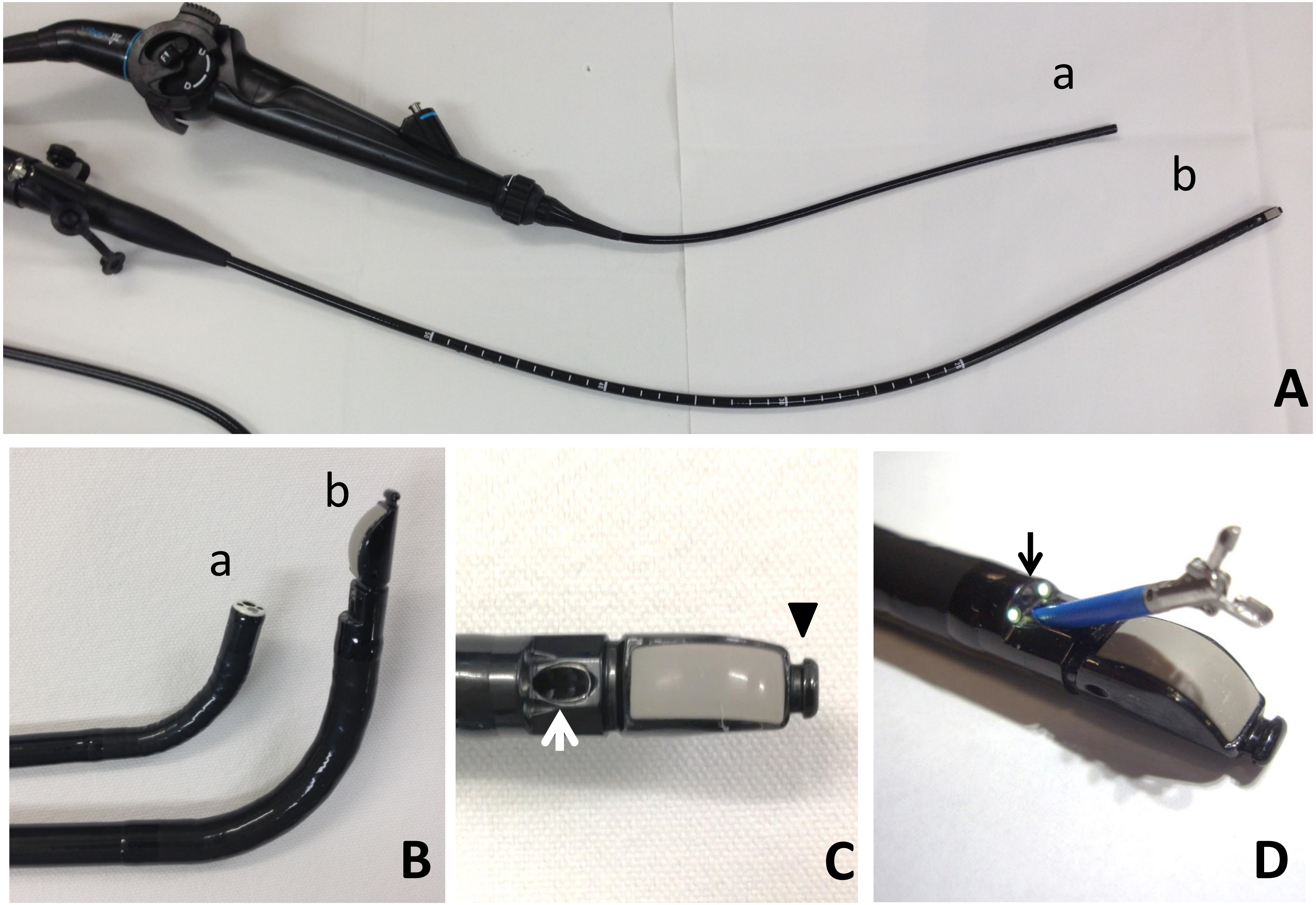


Fig. 1

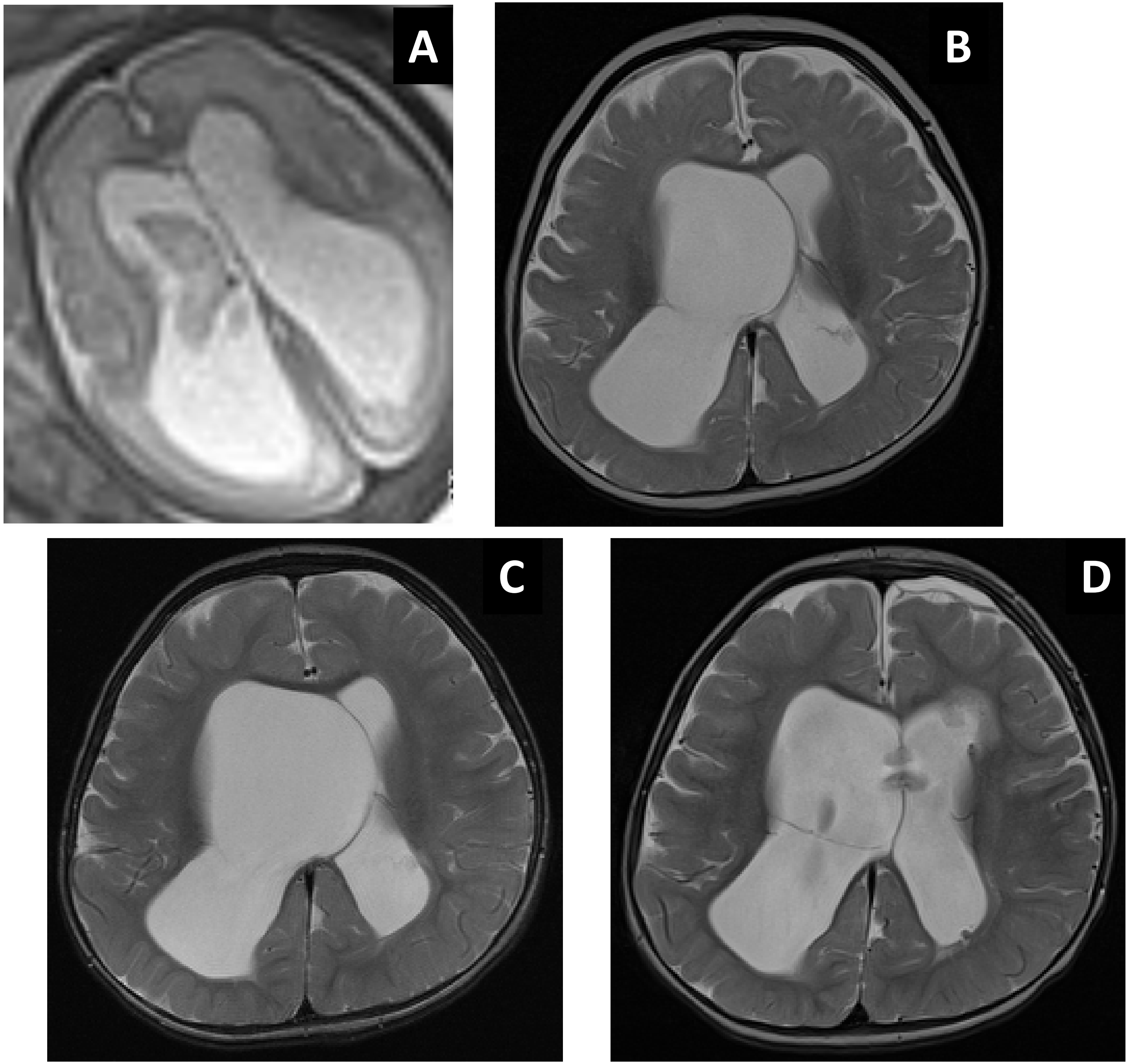


Fig. 2

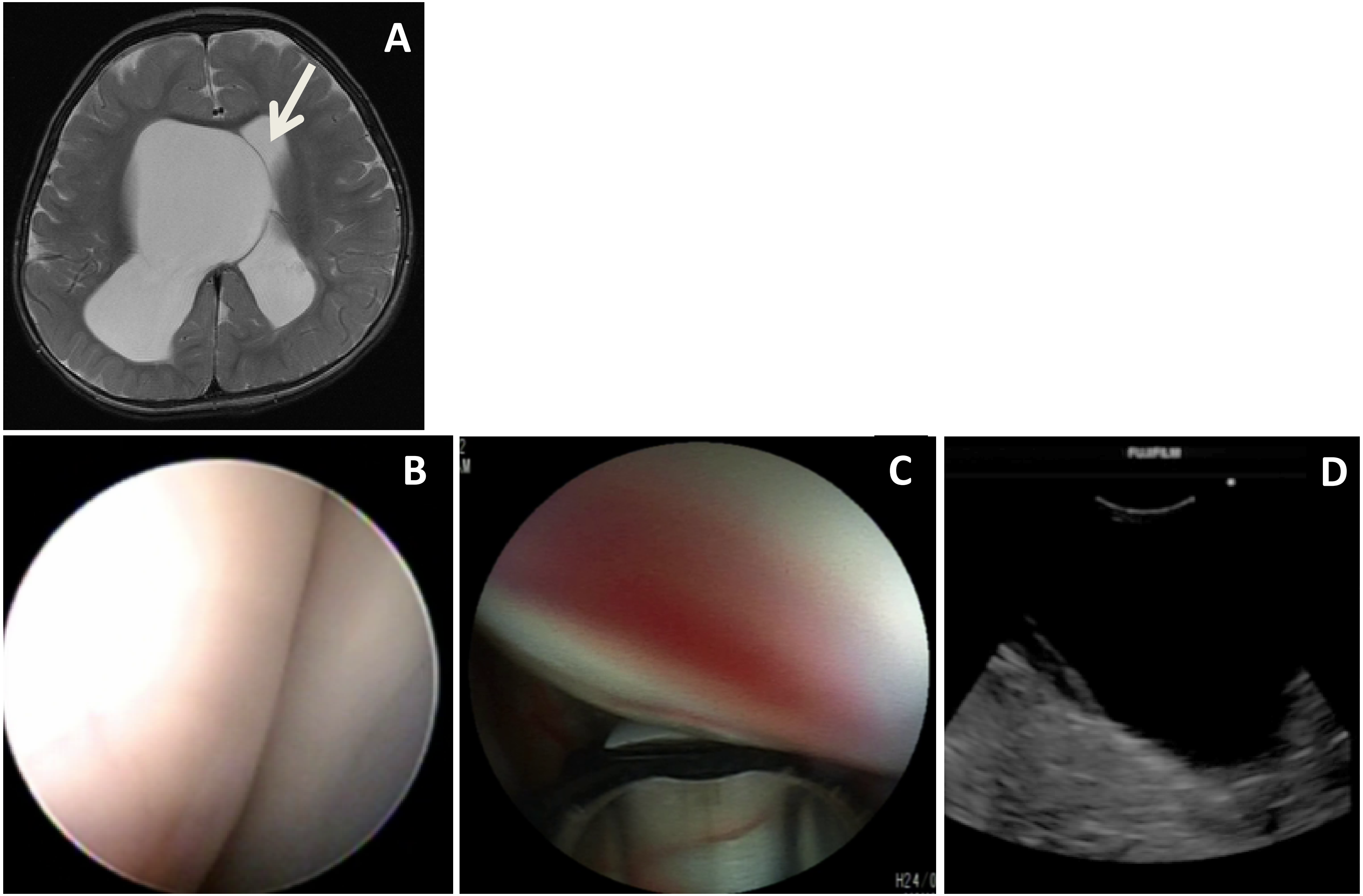


Fig. 3

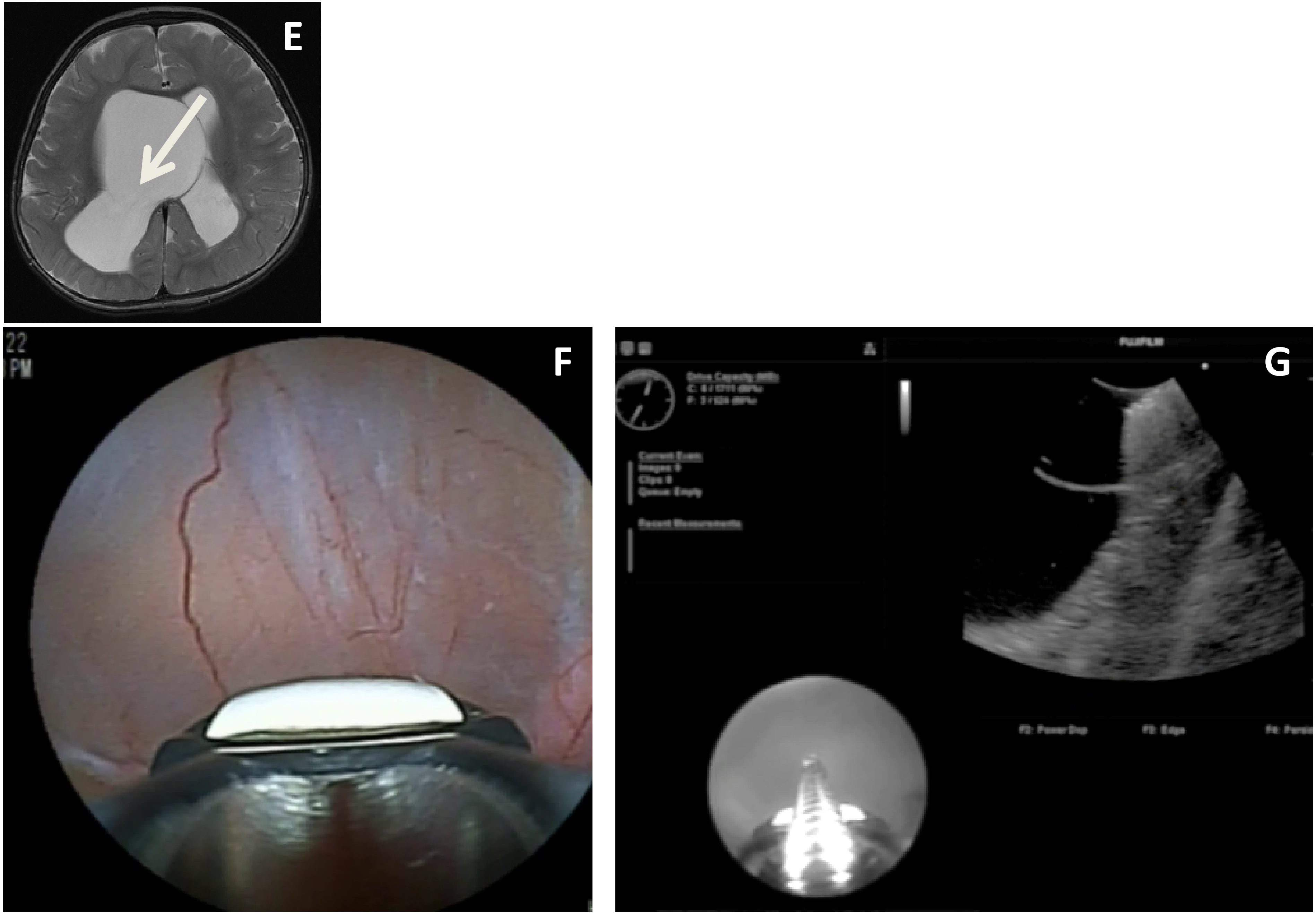


Fig. 3

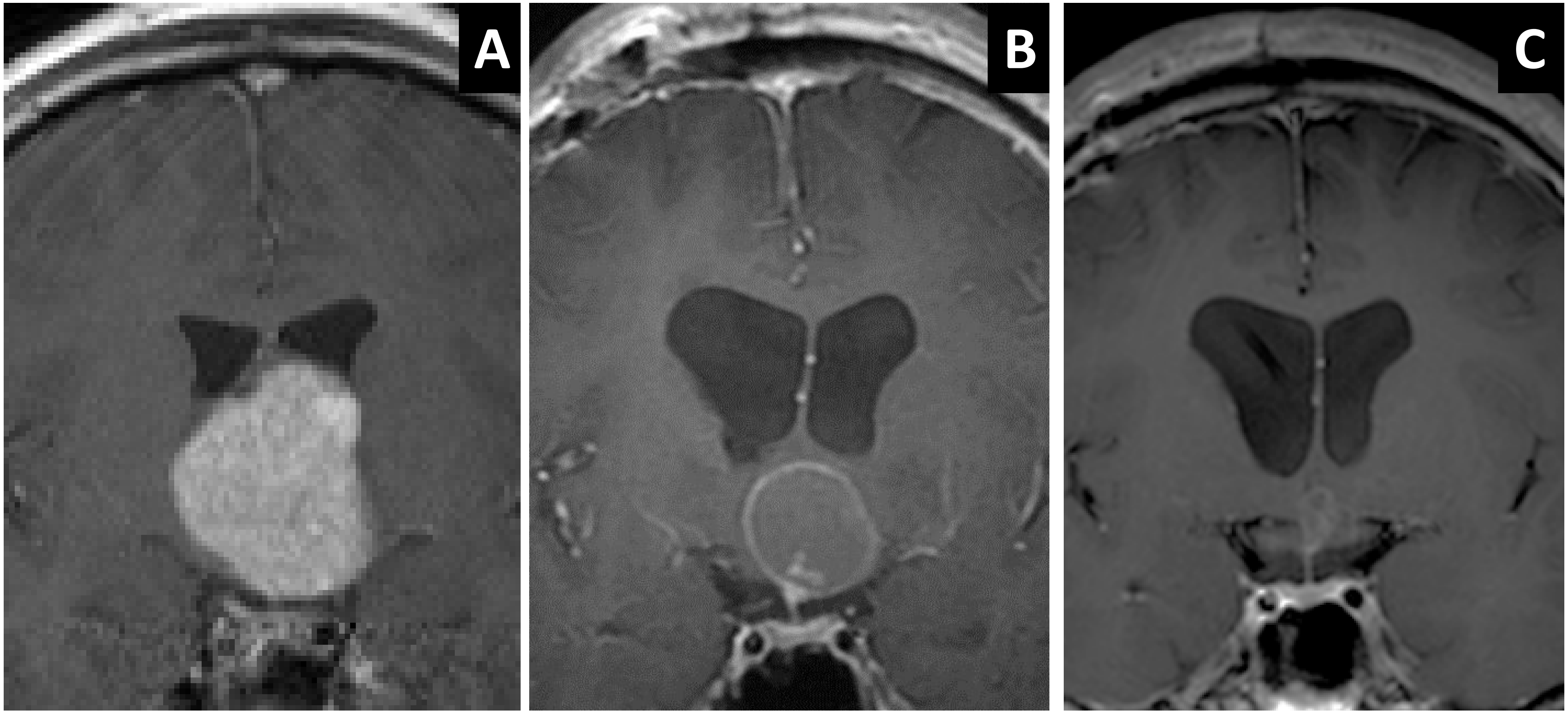


Fig. 4

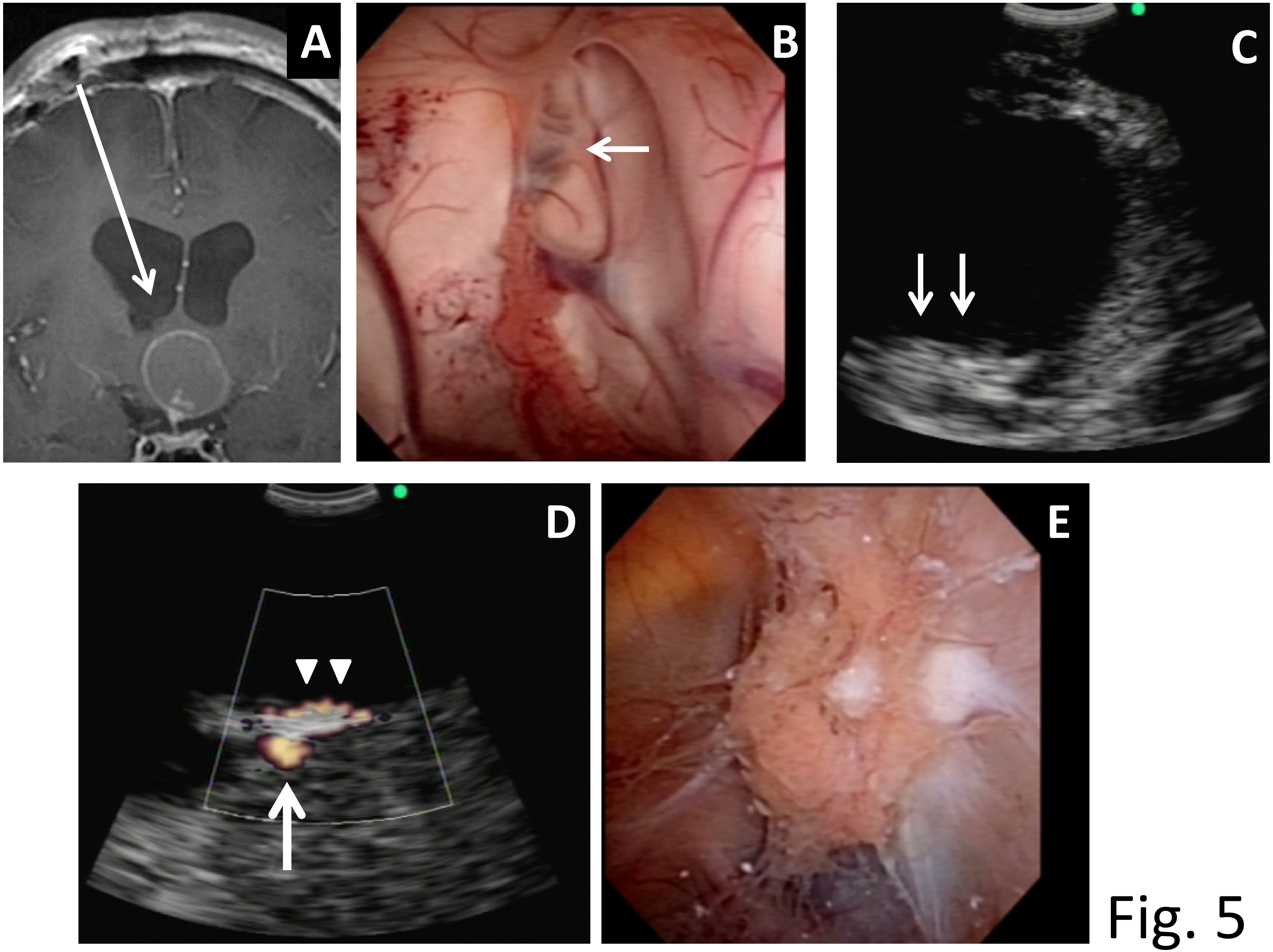


Fig. 5