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Technical Notes & Surgical Techniques

Usefulness of a new neuroendoscope brain cylinder for intracerebral hematoma surgery

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A R T I C L E I N F O

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A B S T R A C T

Objective: In multiple series, intracerebral hematomas have been removed via endoscopic surgery. Although endoscopic surgery with tubular retractors has been able to access deep-seated lesions, it is difficult to confirm the depth of the retractor sheath in the surgical field using only the outer sheath. We built various sizes and lengths of neuroendoscopic cylinders, developed by the Japan Science and Technology Agency (JST) revitalization promotion program, with numerical scales visible during both endoscopic and radiographic procedures.

Method and results: The JST developed cylinders using new techniques for tantalum film implantation to form tubes made of fluorinated ethylene propylene. We successfully and safely removed various hematomas using these cylinders because we were able to clearly visualize the border of the brain parenchyma and the depth from the brain surface in the cylinder. In addition, we confirmed the area from the posterior to anterior horn using a 14-cm long cylinder during a trans-posterior horn approach under continuous irrigation for thalamic hemorrhage with ventricular hematoma. We ensured coagulation at the bleeding point with a bipolar coagulator using a brain cylinder, 12-mm in diameter, in a patient on antiplatelet therapy.

Conclusion: Cylinders equipped with a visible scale for both endoscopic and radiographic procedures, developed by JST programs, potentially provide greater patient safety during endoscopic surgery, negating, in some cases, the need for various inspections during surgery. In future, various sizes and lengths of cylinders might be useful across a variety of cases under endoscopic and radiographic guidance.

1. Introduction

The success of previously reported endoscopic surgery for intracerebral hemorrhage was apparently hampered by impaired visualization of the clot during surgery, which led to relatively low efficiency of hematoma removal [2,3].

Nishihara et al. reported the use of a transparent sheath to guide the endoscope, a simple and unique tool for endoscopic surgery, and described preliminary results of its application in the evacuation of hypertensive intracerebral hematomas [8]. They pointed out that although visualization of the surgical field was improved by their transparent sheath during endoscopic surgery for intracerebral hematoma, it was necessary to assess the tip of the sheath in accordance with its depth and angle [8]. It was recently reported that rigid endoscopic surgery using the ViewSite tubular retractor (Vycor Medical, Boca Raton, FL, USA) was useful for not only intracerebral hematoma but also deep-seated, intra-axial brain tumors [4,10]. These reports proposed that the number of operations using the rigid endoscope for various intracerebral hematomas and tumors will increase in the future. Because the ViewSite tubular retractor was developed as a brain retractor rather than a tool for endoscopy, this retractor may require improvement in shape and length in the context of endoscopic surgery. In addition, it is difficult to confirm the depth of the conventional tubular retractor sheath in the surgical field using only the outer sheath. We consider it important that the cylinder of a neuroendoscopic retractor has the following characteristics: (1) the operator is able to perform puncturing and maneuver the cylinder under endoscopic guidance; (2) the operator and assistant are able to confirm the depth and site of surgical field using a visual scale on the cylinder; (3) the cylinder is equipped with a radiographic and endoscopic visible scale; and (4) various sizes of cylinders are available for application in a variety of surgical scenarios. We have built various-sized cylinders, developed by

Abbreviations: CT, computed tomography; ICP, intracranial pressure; MMT, manual muscle test; MPR, membrane potential resonance

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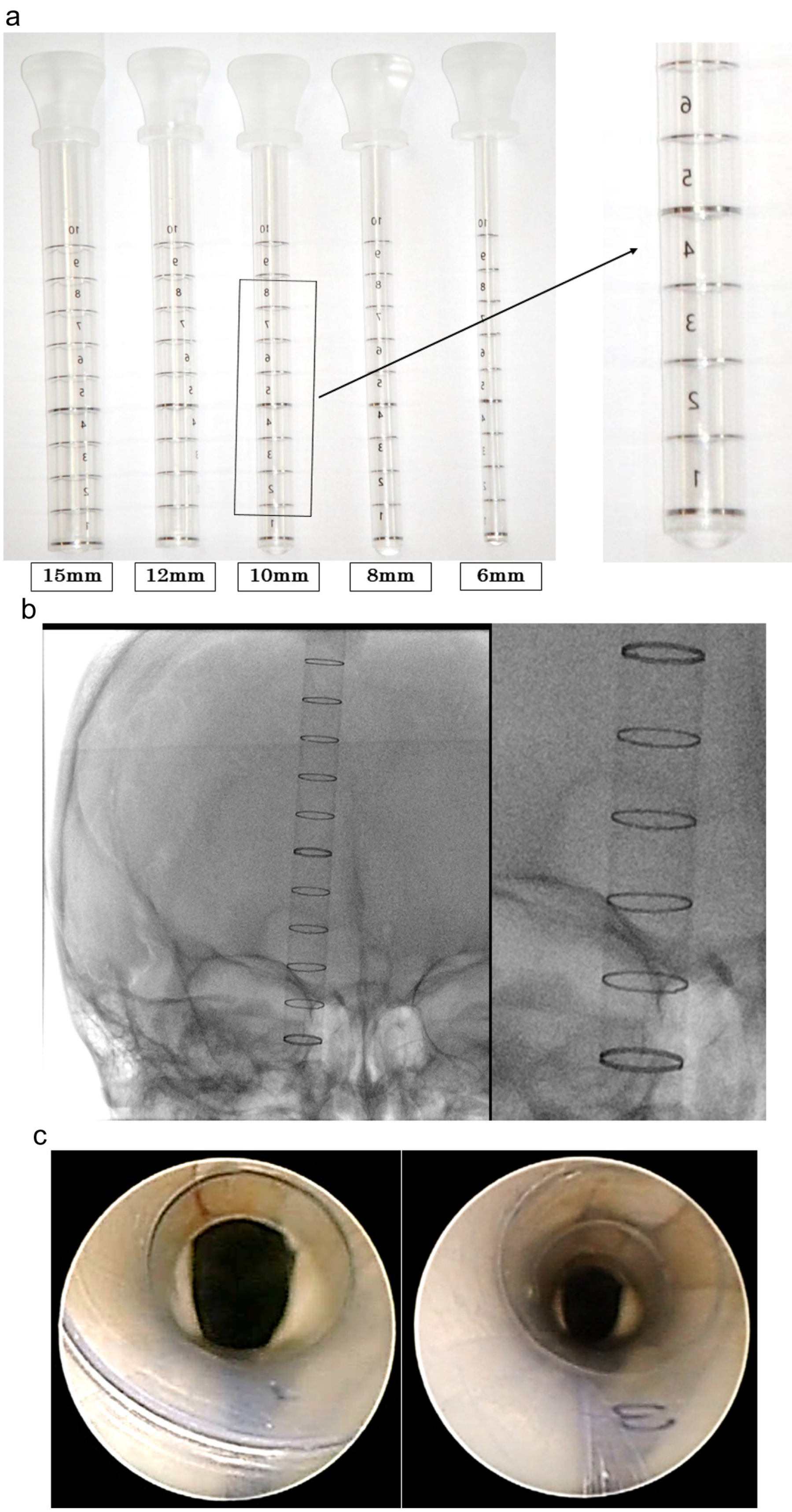

Fig. 1. a The diameter of the brain cylinder is 6, 8, 10, 12, or 15 mm. b The visible scale on the brain cylinder has radiolucency. c The scale and scale numbering of the brain cylinder is confirmed with a rigid endoscope.

Table 1
Characteristics of the study population.

Case. no	Age (yrs), sex	Hematoma location	Pre and post GCS	mRS (discharge)	Background of patient
1	78, M	Lt. combined type	6 → 10	6	Aspiration pneumonia
2	45, F	Rt. cerebellar	6 → 13	5	Rupture of aneurysm with AVM
3	76, M	Rt. frontal lobe	12 → 14	1	
4	50, M	Rt. putamen	9 → 13	2	Transfer by air ambulance
5	65, M	Lt. thalamus, IVH	7 → 12	4	
6	49, M	Bil. IVH	6 → 10	6	Rupture of Acom AN, Aspiration pneumonia
7	73, M	Rt. thalamus, IVH	6 → 10	4	Trans-posterior horn approach under continuous irrigation
8	60, M	Rt. thalamus, IVH	6 → 10	4	Trans-posterior horn approach under continuous irrigation
9	75, F	Lt. combined type	6 → 10	4	Antiplatelet therapy
10	57, M	Rt. thalamus, IVH	6 → 13	3	Trans-posterior horn approach under continuous irrigation
11	64, M	Lt. fronto-parietal lobe, IVH	6 → 13	2	
12	52, M	Rt. putamen	6 → 13	2	
13	84, M	Bil. IVH	6 → 10	6	Rupture of Acom AN, Aspiration pneumonia
14	74, M	Lt. fronto-parietal lobe	8 → 13	1	
15	89, M	Lt. thalamus	7 → 12	6	Aspiration pneumonia
16	83, F	Rt. putamen	7 → 13	3	
17	50, F	Lt. putamen	6 → 13	3	
18	66, M	Lt, thalamus, IVH	6 → 11	5	
19	60, M	Lt. putamen	6 → 13	3	
20	82, F	Rt. combined-type	6 → 10	6	Aspiration pneumonia
21	48, F	Lt. putamen	6 → 13	3	
22	53, M	Rt. putamen	6 → 13	3	
23	40, M	Rt. putamen	6 → 13	2	

GCS, Glasgow Coma Scale; mRS, modified Rankin Scale; AN, aneurysm; SCA, superior cerebellar artery; Acom, anterior communicating artery; AVM, arteriovenous malformation; IVH, intraventricular hemorrhage; M, male; F, female.

the Japan Science and Technology Agency (JST) revitalization promotion program that are furnished with scales visible during both endoscopic and radiographic procedures. We report on the use of these cylinders in clinical cases of intracerebral hematoma.

2. Development of the brain cylinder

2.1. Brain cylinder

The JST developed intraoperative cylinders using new techniques for tantalum film implantation to impress a scale onto tubes made of fluorinated ethylene propylene. After the acrylic inner tube is inserted through the rigid endoscope, the operator is able to puncture and maneuver the cylinder under endoscopic guidance. We built various-sized cylinders with scales that are visible during both endoscopic and radiographic procedures [13]. Five cylinders of diameter 6, 8, 10, 12, and 15 mm are available (Fig. 1a–c), with lengths of either 13 or 14 cm. These cylinders were approved by our institutional ethics committee in November 2014, and we use them only on patients from whom we have obtained full consent. From January 2015 to January 2017, we used the cylinders to operate on 23 cases of intracerebral hematoma (Table 1). No complications were encountered during and after endoscopic surgery while using the cylinder.

2.2. Surgical technique

The surgical procedure was performed with the patient in the supine, lateral, or prone position while under general anesthesia. A 4-cm skin incision was made lateral to the midline, parietal, frontal, and parietal-occipital scalp on the side of the lesion, and a 3 × 3-cm craniotomy was performed. A transcortical puncture was performed using the brain cylinder with a 2.7-mm, 0° endoscope (Storz). When the hematoma was reached, the acrylic inner tube was removed, and a 2.7-mm, 0° endoscope (Storz) and suction tube were inserted through the brain cylinder. When a bleeding point was encountered, the suction tube was changed to a coated suction device and monopolar coagulation was applied through the uncoated tip, or a bipolar coagulator was used while the bleeding was controlled with suction.

3. Presentation of clinical cases

3.1. Case 4: 50-year-old man, right putaminal hemorrhage

3.1.1. History and examination

In June 2016, a 50-year-old-man was sent to our hospital by air ambulance because of sudden altered level of consciousness and left hemiplegia. On admission, he was comatose (Glasgow Coma Scale score 6: eye opening [E], 1; verbal response [V], 1; motor response [M], 4) and exhibited left hemiparesis (manual muscle test [MMT]: 1/5). Computed tomography (CT) revealed a right-side putaminal hemorrhage (Fig. 2a). We performed evacuation of the right putaminal hemorrhage with rigid endoscopic surgery. Postoperative CT showed total removal of the hematoma (Fig. 2b). He was awake (Glasgow Coma Scale score 15: E, 4; V, 5; M, 6) with left hemiplegia (MMT of 3/5), and was transferred to another hospital for rehabilitation.

3.1.2. Operative procedure

We used a cylinder of 10-mm diameter and length of 13 cm. We decided upon the site and direction of puncture after examining the coronal and sagittal images of membrane potential resonance (MPR) with preoperative helical CT. We successfully removed the hematoma using the cylinder, as we were able to clearly visualize the border of the brain parenchyma and the depth from the brain surface along the cylinder (Fig. 2c–d). In addition, the assistant handling the cylinder was able to confirm the border of the brain parenchyma and the depth from the brain surface by recognizing the scale on the monitor and looking directly at the surgical field of the brain surface.

3.2. Case 10: 57-year-old man, right thalamic hemorrhage with intraventricular hematoma

3.2.1. History and examination

In January 2016, a 57-year-old-man was sent to our hospital by air ambulance because of sudden-onset altered level of consciousness. On

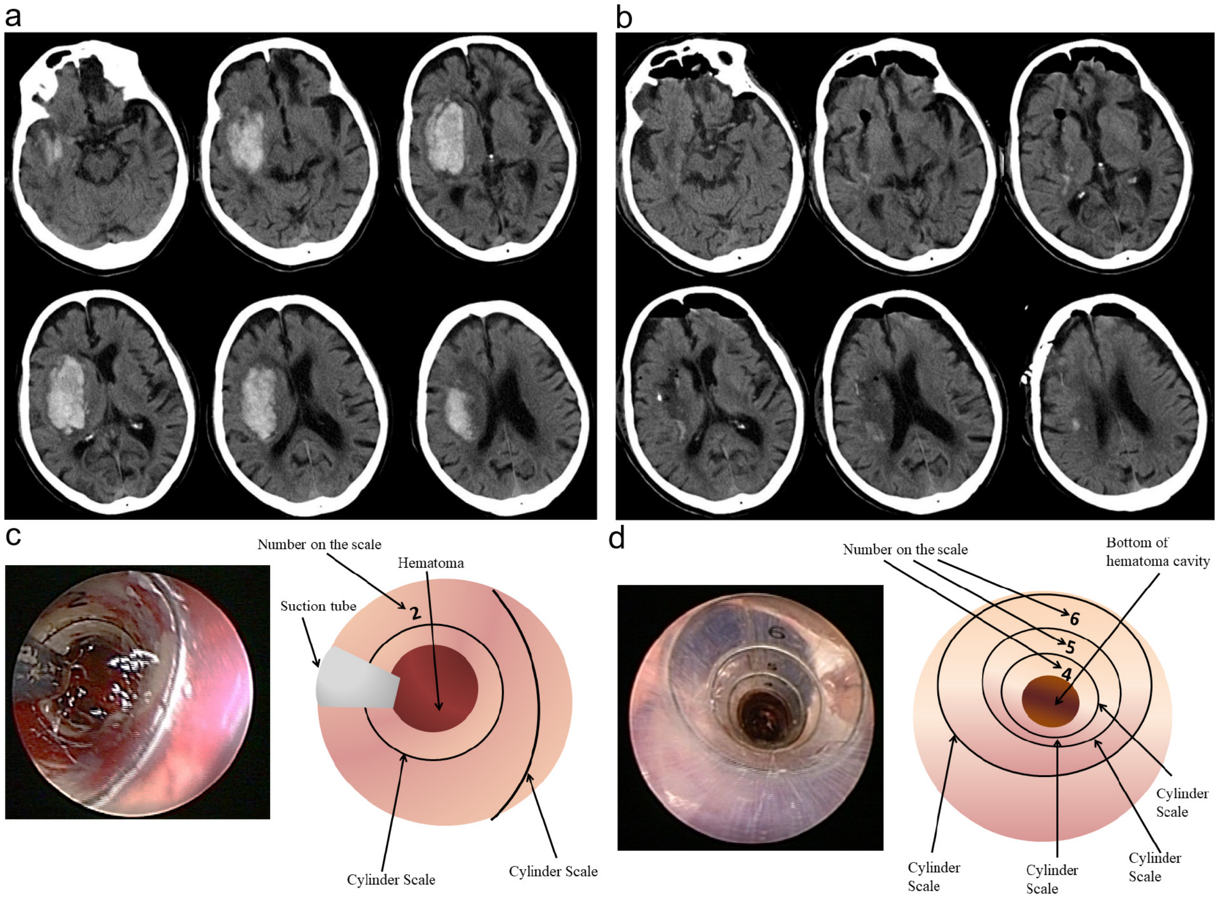

Fig. 2. a Preoperative CT revealed a right putaminal hemorrhage. b CT revealed complete evacuation of the hematoma. c Endoscopic view and schematic showing the border between hematoma and cylinder scale. d Endoscopic view and schematic clearly showing the depth of hematoma cavity with the cylinder scale.

admission, he was comatose (Glasgow Coma Scale score 6: E, 1; V, 1; M, 4) and exhibited tetraplegia. CT revealed a right-side thalamic hemorrhage, intraventricular hematoma, and acute hydrocephalus (Fig. 3a). After carrying out external ventricular drainage and setting up an intracranial pressure (ICP) sensor, endoscopic surgery via the trans-posterior horn approach under continuous irrigation was performed to remove the hematoma (Fig. 3b). Postoperative CT showed total removal of the hematoma (Fig. 3c). He was awake (Glasgow Coma Scale score 15: E, 4; V, 5; M, 6) with left hemiplegia (MMT 4/5), and was transferred to another hospital for rehabilitation.

3.2.2. Operative procedure

We used a 10-mm diameter cylinder with length 14 cm, because previous use of a 13-cm cylinder only permitted observation up to the foramen of Monro. We decided upon the site and direction of puncture after examining the coronal and sagittal images of MPR with preoperative helical CT. First, we inserted drainage tubes into the bilateral anterior horns of the lateral ventricles and placed an ICP sensor. After a rigid scope had been introduced into the bleeding side of the posterior horn of the lateral ventricle, we removed the thalamic and intraventricular hematomas using the rigid scope and a suction tube under continuous irrigation from the bilateral drainage tubes while monitoring the ICP. Confirming the depth of surgical field by consulting the scale on the cylinder through the rigid scope during the operation, we were able to find the rupture point of thalamic hemorrhage in the ventricle and remove the thalamic hematoma (Fig. 3d–e). After removal of the thalamic and ventricular hematoma, we seated the cylinder at the anterior ventricle and found the bilateral external drainage tube and ICP sensor. It would have been impossible to find the external drainage tube running from the posterior to the anterior horn using a conventional tubular retractor with a rigid endoscope (Fig. 3e–f).

3.3. Case 9: 75-year-old woman, left combined-type hematoma

3.3.1. History and examination

In January 2016, a 75-year-old-woman undergoing antiplatelet therapy with clopidogrel and cilostazol was referred to our hospital because of sudden-onset altered level of consciousness. On admission, she was comatose (Glasgow Coma Scale score 5: E, 1; V, 1; M, 3) and exhibited a flexion response with left mydriasis. CT revealed a left-side combined-type hematoma (Fig. 4a), and urgent endoscopic surgery was initiated to remove the hematoma (Fig. 4b). After the operation, she was awake (Glasgow Coma Scale score 13: E, 4; V, 4; M, 5) with right hemiplegia (MMT 2/5). She was transferred to another hospital for rehabilitation.

3.3.2. Operative procedure

We used a cylinder with 12-mm diameter and length of 14 cm. We decided upon the site and direction of puncture after examining the coronal and sagittal images of MPR with preoperative helical CT. After we seated the cylinder at the hematoma under endoscopy, the position of the intracranial hematoma cavity was confirmed by consulting the cylinder scale. Because the patient was medicated with antiplatelet therapy, it was difficult to control the bleeding or oozing from the hematoma cavity using only the suction tube, so we introduced a bipolar coagulator into the cylinder to aid the control of bleeding or oozing under endoscopic guidance (Fig. 4c).

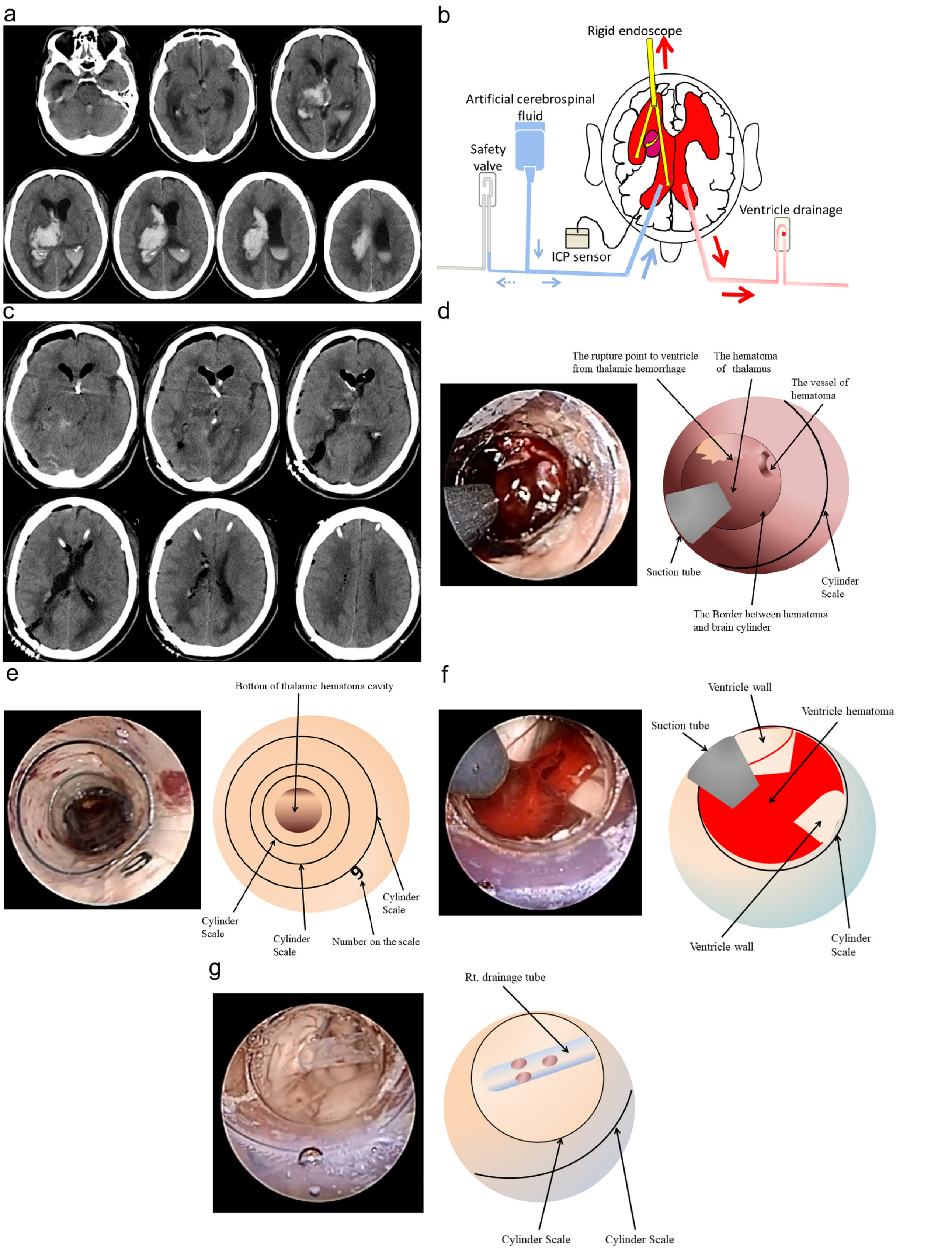

Fig. 3. a Preoperative CT revealed a right combined-type hemorrhage with intraventricular hemorrhage and acute hydrocephalus. b Schematic showing the trans-posterior horn approach under continuous irrigation for thalamic hemorrhage with ventricular hematoma. c Postoperative CT revealed complete evacuation of the hematoma. d Endoscopic view and schematic showing the rupture point from the thalamic hemorrhage into the ventricle and the border between hematoma cavity and cylinder scale.
e Endoscopic view and schematic clearly showing the depth of hematoma cavity with the cylinder scale. f Endoscopic view and schematic showing the right ventricle hematoma and the border between hematoma cavity and cylinder scale. g Endoscopic view and schematic showing the right ventricle drainage tube.

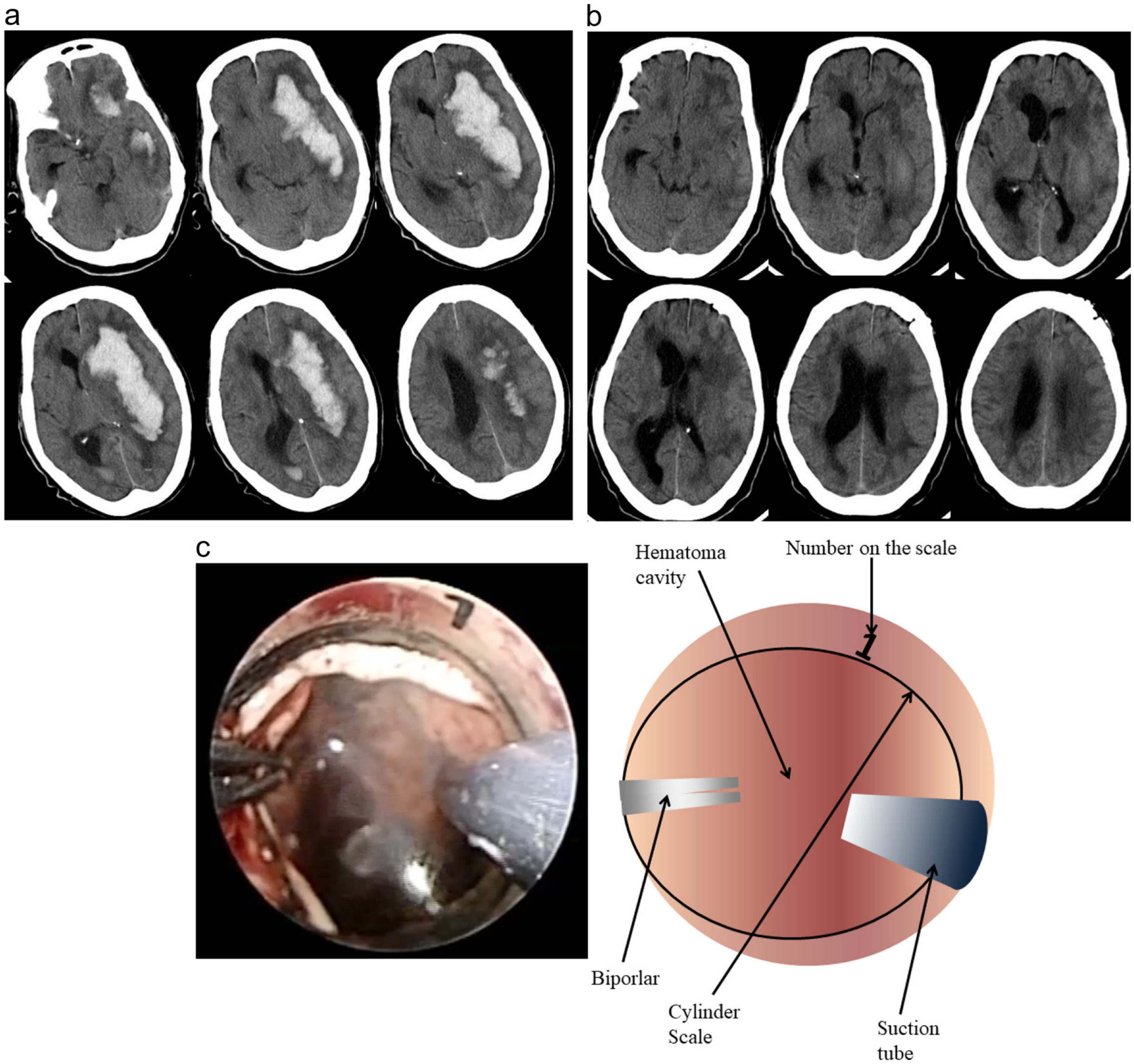

Fig. 4. a Preoperative CT revealing a right putaminal hemorrhage. b Postoperative CT revealing evacuation of the hematoma. c Endoscopic view and schematic showing coagulation of the bleeding point using a bipolar coagulator with suction tube during the endoscopic procedure.

4. Discussion

Craniotomy or CT-guided stereotactic surgery has conventionally been prescribed for the surgical management of intracerebral hematoma. Given the increasing age of the population in Japan, opportunities to treat intracerebral hematoma in the elderly are more frequent than ever. However, craniotomy surgery is burdensome for older patients because of the associated complications and chronic disease, although CT-guided stereotactic surgery for intracerebral hematoma has been reported as being efficacious [5]. While CT-guided stereotactic surgery is useful as a minimally invasive technique, control of bleeding during the procedure is difficult. In 2000, Nishihara et al. reported an epoch-making endoscopic method involving the use of a transparent sheath to guide an endoscope and suction tube with a monopolar coagulator for the removal of hypertensive intracerebral hematomas [8]. However, they pointed out a few problems: (1) the clinician must assess the position of the sheath tip according to its depth and angle; and (2) when an echo guidance system is not available, punctures must be done freehand using a blind technique. We do not often confirm the depth of the surgical field solely according to the outer neuroendoscopic sheath. Since both the operator and the assistant, as well as ancillary staff, can confirm the depth of the surgical field by checking the brain cylinder scale on the endoscopic monitor and radiographs, the surgery will potentially be safer in comparison with conventional endoscopy. In addition, because it is possible for an assistant to handle the brain cylinder while monitoring the numerical scale at the brain surface during endoscopic surgery, further safety is ensured. Furthermore, it was thought useful that surgery was possible while confirming the distance from the brain surface to important structures such as the brainstem and encapsulation using the scale on the brain cylinder in this study [13].

While it is difficult to control any bleeding with the suction tube alone using a monopolar coagulator in cases of intracerebral hematoma under anticoagulant and antiplatelet therapy, endoscopic surgery using ViewSite (Vycor Medical, Boca Raton, FL, USA) often enables us to perform the operation with a bipolar coagulator and suction tube to better control the bleeding. In the present case 3 (case 9 in Table 1), use of such a bipolar coagulator and suction tube within the 12-mm brain cylinder allowed us to safely perform endoscopic surgery for the evacuation of intracerebral hematoma, even when the patient was on antiplatelet medication. The use of a ViewSite retractor in endoscopic surgery for the removal of deep-seated tumors was previously reported

[10]. Since the ViewSite was not developed for endoscopic surgery, it was thought that this tool was not suitable in shape and length for endoscopy. It was reported that while using a microscopic approach to remove deep-seated lesions, one could easily crush the brain tissue with excessive retraction using the instrument, leading to cortical ischemic complications [11]. Others, however, have pointed out that the extent of damage done by compression of the neighboring brain tissue while using a tubular retractor is relatively minor [9]. We propose that the brain cylinder is potentially a useful endoscopic surgical instrument for the removal of deep-seated brain lesions. The usefulness of a rigid endoscope to remove thalamic and ventricular hemorrhage was recently reported [14]. We performed endoscopic surgery under continuous irrigation while monitoring the intracranial pressure (trans-posterior horn approach under continuous irrigation) for thalamic hemorrhage in patients with acute hydrocephalus caused by intraventricular hematoma [12].

In this endoscopic approach, frequent confirmation of dimensions of the hematoma cavity, the cerebral ventricle, and the depth of the surgical field is very important. When using the conventional sheath, confirmation of the foramen of Monro was limited by the approach from the posterior horn in rigid endoscopic surgery. When we used the brain cylinder with a length of 14 cm and diameter of 10 mm, we successfully monitored the drainage tube and the ICP sensor inserted in the anterior horn, and measured the extent of extraction of the hematoma, thus verifying its usefulness.

The BrainPath tube (NICO Corporation, Indianapolis, IN, USA) is a useful endoscopic surgical instrument for cases such as intracerebral hemorrhage and brain tumors under a navigation system [6]. However, it may be difficult to use in facilities that do not have such a system. Although the BrainPath tube is currently not commercially available in Japan, since the brain cylinder enables puncturing under endoscopy, it is possible to place the brain cylinder while confirming the intracranial environment with the endoscope. Moreover, because we can see the scale using a general radiological instrument and XperGuide (Philips Healthcare, Eindhoven, the Netherlands), we can determine the puncture direction and depth. For these reasons, in a facility that does not have a navigation system, it is likely that the brain cylinder will be helpful in performing endoscopic surgery more safely [1]. Recently, an effective approach was reported for the treatment of deep-seated brain lesions using diffusion tensor imaging tractography and a navigation system to prevent damage to various neurological tracts when inserting tubular retractors [4,10]. The brain cylinder that we developed might also be used under such circumstances. In addition, since while using the brain cylinder it is easy to assess the intraoperative depth and position via an endoscope and general radiographic apparatus, it should be possible to safely perform endoscopic evacuation of intracerebral hematoma and biopsy of brain tumors in facilities not equipped with a navigation system or echo system. Furthermore, we believe that the brain cylinder may be applied in conjunction with XperGuide needle guidance because one can visualize the scale on the cylinder via X-ray. Nevertheless, the influence of the cylinder on the normal brain must be considered as a possible future concern [1]. Nakajima et al. described the problem as follows: in the evaluation of local brain circulation and metabolism using positron emission tomography before and after the ventricle puncture procedure, clinical manifestations do not develop, but the procedure can cause local brain circulatory disease at the site of the puncture [7]. We thus consider that damage to the normal brain caused by inserting a sheath of wider diameter than that of a normal cerebral ventricle puncture needle is an important problem to be addressed in the future. Furthermore, we believe it necessary to develop and improve the hardness, length, and smoothness of the groove on the cylinder. In addition, since the symptoms of hemiparesis did not deteriorate after surgery in this study, we think that hemiplegia is not caused by the device or operation. However, we must still examine our surgical techniques using the brain cylinder in future.

5. Conclusion

Cylinders with a visible scale for both endoscopic and radiographic use as developed by JST programs may provide greater patient safety during endoscopic surgery without navigation and echo systems. In addition, endoscopic surgery using various sizes of brain cylinders may be possible for the evacuation of cerebral hematoma associated with difficult control of bleeding and treatment of deep-seated lesions. Since the scale marked on these cylinders is visible on X-ray, they may be used in conjunction with XperGuide as well as wider applications of endoscopic surgery.

Conflict of interest

The authors report no conflict of interest concerning the materials or methods used in this study or findings specified in this paper.

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Disclosures

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.inat.2018.10.001.

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