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Evaluation of the Usefulness of an Expandable Stent for Establishing Patency in Endoscopic Third Ventriculostomy: A Fresh Cadaveric Study

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ABSTRACT

AIM: To demonstrate the feasibility of stent application to the third ventricular floor during endoscopic third ventriculostomy (ETV).

MATERIAL and METHODS: We performed the ETV procedure on four fresh cadavers not exposed to head trauma. The neuroendoscope was introduced into the third ventricle under ultrasonography guidance. The stoma was opened with a neuroballoon in the third ventricular floor in three cases and with the catheter carrying the stent in the remaining case. The balloon-expandable stent was 8 mm in length and 4 and 4.5 mm in diameter. The distal end of the stent was placed in the prepontine cistern, without contact with the vascular structures in the cistern, and the proximal end was placed in the stoma, with its proximal end in the third ventricle.

RESULTS: In all the cases, the stent was fixed in the targeted position. Then, the head cavity was opened. The brain was extracted from the skull for pathological analysis. The stents were placed in front of the mamillary bodies in all four cases, fixed around the stoma, which was opened previously. No significant compression on the structures around the prepontine cisterna and on the basilar artery was observed.

CONCLUSION: Expandable stents may be useful and technically safe in creating and maintaining the stomal opening in ETV.

KEYWORDS: Hydrocephalus, Endoscopic third ventriculostomy, Stent, Cardiac stent, Stoma closure

INTRODUCTION

Hydrocephalus is a clinical condition caused by increased production of cerebrospinal fluid and decreased absorption or impaired cerebrospinal fluid (CSF) circulation, and its treatment is surgical. The standard surgical treatment methods are ventriculoperitoneal shunt and endoscopic third ventriculostomy (ETV). In shunt insertion surgery, which is an effective method, complications such as infection, disconnection, occlusion, and malposition of the catheters may occur. ETV is not only considered a standard and safe treatment method for obstructive hydrocephalus but also has been performed for some other hydrocephalic conditions such as normal-pressure hydrocephalus in recent years (3,4,6,16,18). In ETV surgery, a neuroendoscope is targeted to the ventricular system and a stoma in the floor of the third ventricle is opened to connect it with the prepontine cistern. As this stoma remains open and functional, allowing CSF circulation, the symptoms of hydrocephalus regress.

Despite the current advanced technological developments in neuroendoscope systems, one of the most common causes

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of early or late failure after third ventriculostomy surgery is complete or partial closure of the opened stoma. The stoma may close owing to fibrosis, the arachnoid membrane, hemorrhage, and infection. Patients at risk of closure of the stoma cannot be identified, and the risk cannot be evaluated before surgery. In the literature, the same surgical procedure is recommended for the second treatment in patients with recurrent hydrocephalus after ETV, and the most common finding during surgery is complete closure of the opened stoma (3,8,11,12). A surgical innovation that may prevent stoma reclosure after ETV will eliminate the most common cause of failure of a proven procedure and prevent repetitive surgeries. The aim of this study was to technically evaluate the stent placement in fresh cadavers to prevent reclosure of the stoma which is opened in the third ventricular floor during the ETV procedure.

MATERIAL and METHODS

The study was performed with four fresh cadavers of unknown identity who had not been exposed to head trauma and had not undergone any surgery on the head region and were brought to the autopsy in Institute of Forensic Medicine Department, Ministry of Justice within the first 24 hours after death. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

A burr hole was opened in each cadaver, just in front of the coronary suture in the right frontal region, 2–3 cm lateral to the midline, and the dura mater was exposed (Figure 1A, B). After the dural incision, both the lateral and third ventricles were visualized with the puncture probe of the intraoperative ultrasonography device (Hitachi Arietta 70, Tokyo, Japan). The right lateral ventricle was punctured with a neuroendoscope (Image 1S Three-Chip, Karl Storz, Germany) via ultrasonography guided puncture technique (Figure 2A-C) (17).

The endoscope was introduced into the third ventricle through the right foramen of Monro. The stoma was opened with a neuroballoon (NeuroBalloon Catheter, Integra, USA) in the third ventricular floor in three cases and with the catheter carrying the stent in the remaining case (Figures 3A-C, 4A-C).

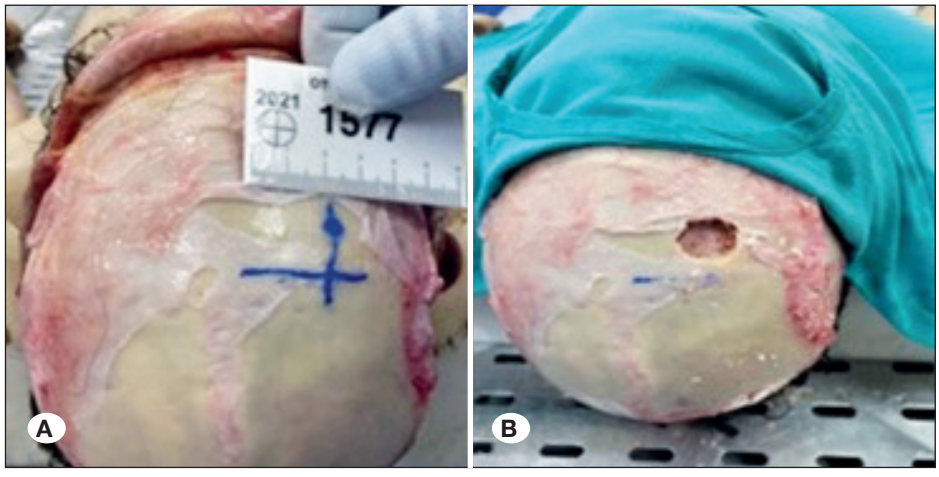

Figure 1: A) The stent targeted just in front of the coronary suture on the right and 2–3 cm lateral to the midline. **B)** A burr hole opened to the targeted point.

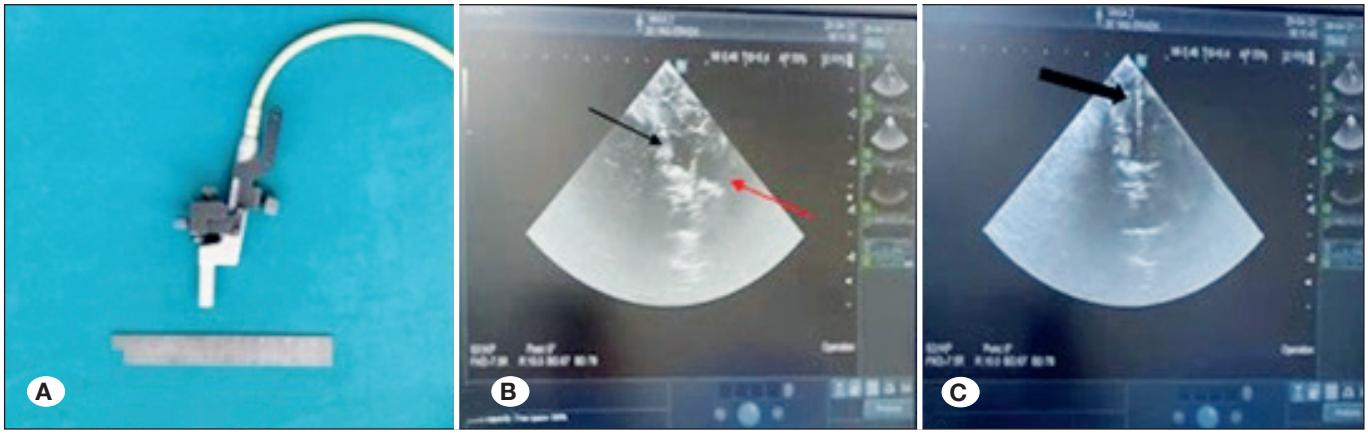

Figure 2: A) The burr hole probe used in the intraoperative ultrasonography. **B)** Visualization of the lateral ventricles with intraoperative ultrasonography (black arrow: right lateral ventricle, red arrow: left lateral ventricle). **C)** Neuroballoon catheter view in the right lateral ventricle (thick black arrow).

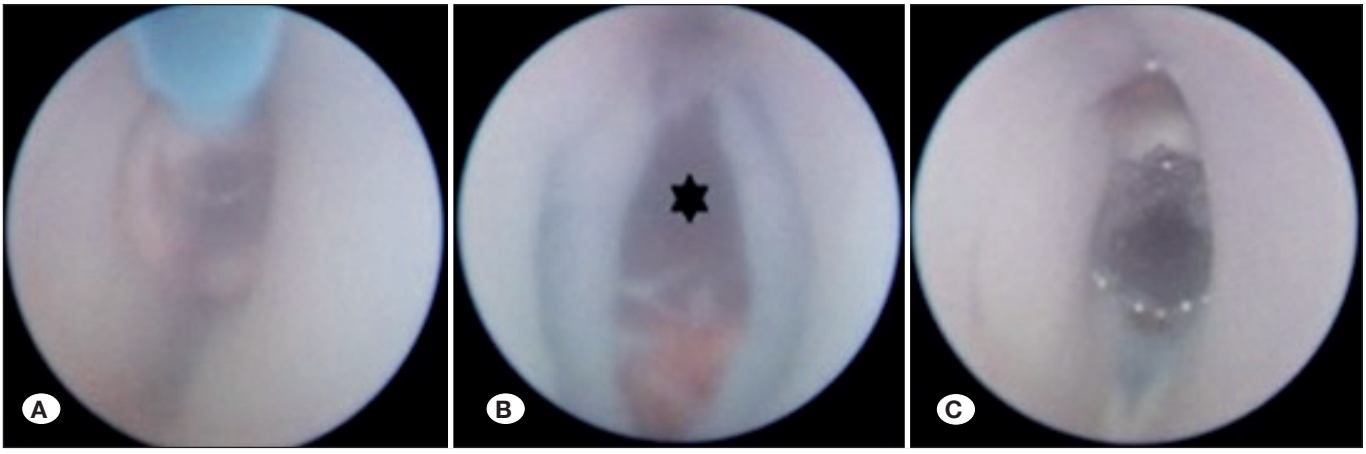

Figure 3: A, B) Stoma opening with a neuroballoon catheter (*prepontine cisterna). **C)** Placement of the stent, which was opened with a balloon, into the stoma.

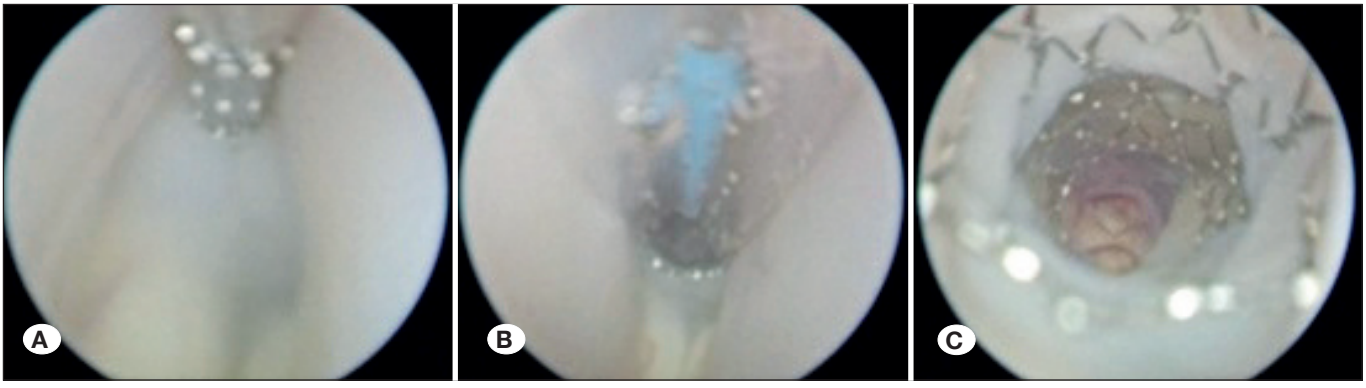

Figure 4: A, B) Opening the stoma with the catheter carrying the stent. **C)** Stent placement at the same time.

Then, a balloon-expandable cobalt chromium coronary stent system (NexGen, Meril Life Science Pvt. Ltd, Vapi, Gujarat, India), which was 8 mm in length and 4 and 4.5 mm in diameter, was passed through the endoscope and forwarded into the stoma. The distal end of the stent was placed in the prepontine cistern, without contact with the vascular structures within the cistern, and the proximal end was placed in the stoma, with its proximal end in the third ventricle. Then, the stent was opened with a balloon, the stoma was expanded, and the stent was fixed. Then, the endoscope system was removed, and the procedure was terminated.

RESULTS

All four cadavers were male. Their mean age was 30.25 years (range, 5–56 years). One cadaver (25%) was a pediatric case, and three cadavers (75%) were adults (Table I). All the cases were selected from cadavers that were not exposed to head trauma and had not undergone an operation on the head region. All the cadavers were autopsied within the first 24 hours after death.

In all four cases with an endoscope-assisted stent placement, the stent was fixed in the target position. Then, the head cavity was opened. The brain was extracted from the skull for pathological analysis. The stents were placed in front of the mamillary bodies, fixing them around the stoma, which was opened previously in all four cases. No significant compression on the structures around the prepontine cisterna and on the basilar artery was observed. After making sure that the stents did not change their positions, they were removed from the stoma (Figure 5A-C).

Table I: Cadaver Characteristics

Case	Age	Gender	Cause of death	Head trauma
1	5	Male	Drowning in water	No
2	30	Male	Drug intoxication	No
3	30	Male	Substance intoxication	No
4	56	Male	Myocardial infarction	No

DISCUSSION

Hydrocephalus continues to be the subject of investigation and research by clinicians because it causes severe neurological symptoms in patients, entails high treatment costs, and still has a relatively high congenital incidence

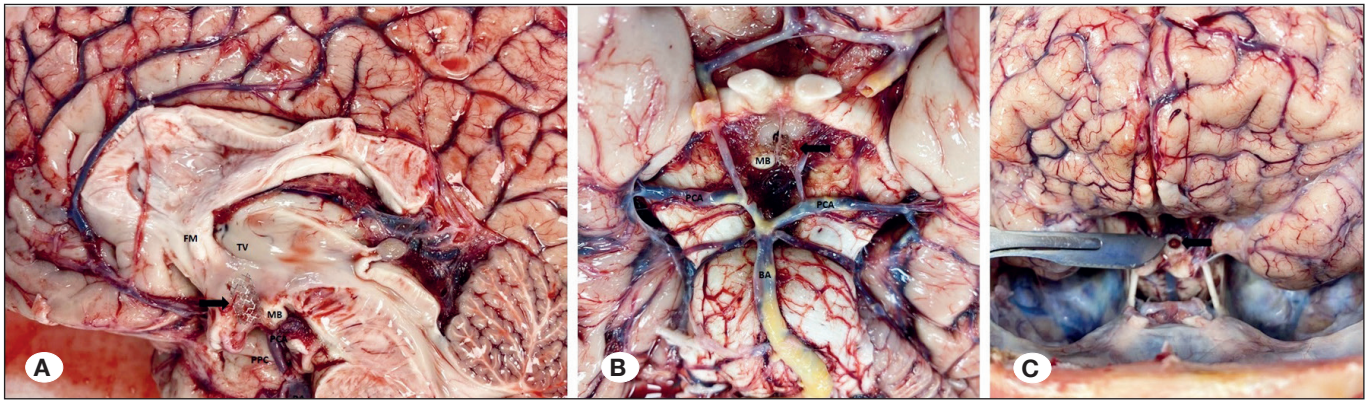

Figure 5: Positions of the stents after brain dissection. **A)** Lateral view, **B)** inferior view, **C)** anterior view. (**black arrow:** position of the stent, **BA:** basilar artery, **FM:** foramen of Monro, **MB:** mammillary body, **PCA:** posterior cerebral artery, **PPC:** prepontine cistern, **TV:** third ventricle).

(approximately 84.7 in 100,000 persons) (9). Despite that ETV, which is one of the treatment methods for hydrocephalus, is safe and effective, patients may require a second surgery because of closure of the opened stoma during the follow-up period. The most valid method for evaluating the stoma opening is cine-phase contrast magnetic resonance imaging (MRI). However, after ETV, whether the problem is caused by stoma closure or an absorption problem in patients for whom treatment is initially beneficial but later lost its effect could not always be clarified. This distinction is much easier to make in patients with a stoma opening made using a stent. In their study, Faggin et al. found that the etiology of hydrocephalus did not make a difference in the early period failure after ETV. Especially in patients who underwent ETV for postinfectious or posthemorrhagic hydrocephalus, cine-phase contrast MRI performed in the early period showed narrowing of the stoma and increased ventricular dimensions, even in asymptomatic cases. This indicates the importance of maintaining the stoma opening (1,2).

No consensus has been reached on the size of the stoma. Grant and McLone opened a stoma of approximately 2.5 mm and reported that they did not detect any closure in the stoma in the long-term. Unsuccessful cases were reported by Jones et al. and Hayashi et al. despite opening stoma of approximately 5 and >5 mm, respectively (5,7,10). Endoscopic stent placement may be used when performing the ETV technique to prevent reclosure of the stoma In our study, after performing ETV in four cases with ultrasonography guidance, we placed a stent in the stoma in the third ventricular floor under neuroendoscopic guidance. Stenting was performed with a 100% success rate in our cases, with a mean patient age of 30.25 years. When the brain extracted from the skull was examined macroscopically after the procedure, we observed that the stent material in all four cases remained at the level of the stoma opening.

No studies have yet been reported on the placement of this type of stent in the stoma opening in the third ventricular floor. In some studies, a catheter was passed through the stoma. The materials used in previous studies, referred to as “stents,” were generally made of silicone catheter pieces. The most common reported problem with this stent technique is stent dislocation. In the silicone-stented ETV study by Schulz et al., after the standard ETV procedure was performed in nine patients, a silicone catheter containing barium sulfate was placed into the prepontine cistern from the opened stoma with the help of an endoscope, and the proximal end of the catheter was connected to the pediatric reservoir placed over the burr hole to prevent dislocation. Thus, the stoma opening was secured. At follow-up, the catheter was found to have been dislodged and positioned in the third ventricle as a result of the progression of hydrocephalus and the related macrocephaly in only one patient. In other patients, the catheter remained in the appropriate position. A standard ventricular catheter and reservoir were used in this study. The stent placed in the stoma was not a featured stent (15).

In the study of Pitskhelauri et al., microsurgical resection via the anterior transcallosal route and fenestration to the third ventricular floor were performed for brain tumors extending to the anterior of the third ventricle. One end of the 6- to 7-cm-long silicone catheter with holes on both ends was leaned against the upper wall of the lateral ventricle, the other end was placed between the basilar artery and the clivus in the prepontine cisterna, and a cuff close to this end was supported by Liliequist’s membrane to prevent caudal dislocation (14).

Catheters, which could not be expanded, cannot be attached to the edges of the stoma, so they may be displaced by movement or pulsation and cannot fulfill the desired function after a while. For this reason, the stents used in our study were selected from among expandable cardiac stents. We thought that expandable stents (because they fit on the sides of the stoma opening) would prevent stent movement and migration. We observed that the catheters carrying the expandable stents passed through the working cannula of the neuroendoscope without any problem. In addition, although we used NeuroBalloons for ventriculostomy in three patients in our study, we observed that the balloon in the catheter carrying the stent, which was inflated to open the stent, was sufficient to widen the stoma opening in the fourth patient. This technique would make the use of NeuroBalloons unnecessary during the procedure and could significantly reduce the cost.

Coronary stents are tubular metal devices used to open stenotic coronary arteries in the treatment of underlying atherosclerotic disease. Stents with different designs are available for endovascular use, such as self-expandable bare metal stents, stent grafts covered with various materials, and balloon-expandable metallic stents (13). We used balloon expandable stents in our study. These stents are used in the treatment of occlusive atherosclerotic coronary artery diseases. Owing to their design that allows coronary artery stents to be expanded with the balloon on which they are loaded, it is possible to expand them easily in the desired localization. In addition, owing to their low profile, they are easy to navigate and can be easily passed through low-diameter lumens and catheters. Drug-coated metallic stents have also been made available in the market to reduce and prevent smooth muscle cell proliferation or intra-stent stenosis due to intimal hyperplasia in metallic stents placed in bare arteries. Thereby, stent openings can be provided for a longer period. The drugs like sirolimus, zotarolimus, or paclitaxel commonly used in drug-eluting stents block signal transduction and cell cycle progression at different phases, thereby blocking smooth muscle cell proliferation or intimal hyperplasia in the stented artery region. This prevents the development of intra-stent stenosis. It is theoretically possible to prevent intra-stent stenosis that may develop secondary to granulation tissue in bare metallic stents placed at the base of the third ventricle by using drug-coated stents. The effects of drugs/materials to be added to the stent for this purpose should be studied with animal models.

The stents used in our study provided high satisfaction results in terms of creating and preserving the stoma opening created in the third ventricular floor. However, designing the stents used during the procedure according to their intended use will prevent the stoma from closing in a more stable condition and will increase the effectiveness of the procedure.

The observed and predicted limitations of the stents used in our study were as follows:

- The stents were not retractable after opening. The collectible feature of the stent will facilitate the correction of the location of stents that are expanded at the wrong point or observed to compress the neurovascular structures after expansion.
- An easy-to-revise design would be appropriate considering the situations that require the stent to be removed for some reason (i.e. infection, migration).
- The migration may occur in vivo despite the fixed position of the stent.
- Methods such as the use of materials to prevent fibrosis or infection associated with the use of the stent and impregnation of the material with antibiotics or antifibrinolytics may also be beneficial to prevent the above- mentioned complications.
- The material to be used for the stent mesh should be MRI compatible.
- Considering the diversity of the population that require the use of stents (children, men, women, etc.), stent options in various sizes are needed.

CONCLUSION

The effectiveness of ETV for the treatment of hydrocephalus has been proven. The most important obstacle to the long-term success of this method is the closure of the stoma opening. Stent use may be an effective method for maintaining patency. As a result of our study, we observed that expandable stents can be successful and technically safe in creating and maintaining the stomal opening. However, long-term results must be obtained in large series using stents designed for application during ETV.

AUTHORSHIP CONTRIBUTION

Study conception and design: AA, TCU, ID

Data collection: AA, ID, HED, CK

Analysis and interpretation of results: TCU, ID

Draft manuscript preparation: ID, HED

Critical revision of the article: AA, TCU

Other (study supervision, materials): AS, MB

All authors (AA, TCU, ID, HED, CK, MB, AS) reviewed the results and approved the final version of the manuscript.

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