Abstract

**Background:** To assess the treatment of posthemorrhagic hydrocephalus with accentuated lateral ventricles dilatation by employing a single biventricular neuronavigation-assisted transseptal-implanted catheter with programmable valve and distal peritoneal derivation.

**Methods:** A neuronavigation-assisted single transseptal biventricular catheter implantation with distal peritoneal shunt system was performed in 11 patients with posthemorrhagic hydrocephalus and accentuated lateral ventricles dilatations between 2001 and 2010. Patients with concomitant third ventricle dilatation were excluded. Several sequential frustrated attempts of temporary drainage occlusion on both sides confirmed the isolation of the lateral ventricles. Neuronavigation was employed to accurately establish the catheter surgical corridor (trajectory) across the lateral ventricles and throughout the septum pellucidum. The neurological and radiological outcomes were assessed at least 6 months after the procedure.

**Results:** Catheter implantation was successfully performed in all patients. Only one catheter was found to be monoventricular on delayed computer tomography controls. Procedure-related complications (bleeding of infections) were not observed. No additional neurological deficits were found after shunt surgery. Six months after procedure, none required additional ventricular catheter implantations or shunt revisions. Radiological and clinical controls confirmed the shunt function and the improved neurological status of all patients.

**Conclusion:** Single neuronavigation-assisted transseptal-implanted biventricular catheter is a valid option for the treatment of posthemorrhagic hydrocephalus with accentuated lateral ventricles dilatation. This technique reduces the number of catheters and minimizes the complexity and timing of the surgical procedure as well as potential infection’s risks associated with the use of multiple shunting systems.

**Key Words:** Posthemorrhagic biventricular hydrocephalus, transseptal catheter
INTRODUCTION

Massive supratentorial intraventricular hemorrhage (IVH) can occlude both foramina of Monro and often result in serious clinical complications in adults as well as premature children. At admission, most of these patients require a biventricular external drainage. After clearing of the cerebrospinal fluid (CSF), the patient’s clinical follow-up and their computed tomography (CT) scans and magnetic resonance images (MRIs) determine the residual distal CSF obstruction and the needs for shunt procedures.

Usually, in patients with a residual accentuated dilatation of both lateral ventricles due to the occlusion from both foramina of Monro, a biventricular catheter derivation with a Y-connector or two separated shunt systems will be commonly employed. Recent advances in endoscopy and neuronavigation techniques have additionally expanded the treatment’s options for these patients. Endoscopic third ventriculostomy and image-guided endoscopic fenestration of the septum pellucidum has been reported to treat different forms of hydrocephalus.[1,12,26]

For selected cases, endoscopy techniques can offer substantial advantages over shunting procedures. Unfortunately, various post-treatment complications such as subdural collection owing to rush decompression or post-procedure CSF fistulas can impair the improvement of these patients. Furthermore, in some of them, a distal residual CSF passage obstruction subsequently demands a ventriculo-peritoneal shunt placement. This study assesses the treatment of posthemorrhagic hydrocephalus with accentuated lateral ventricles dilatation by employing a single neuronavigation-assisted transseptal biventricular-implanted catheter as a part of a shunt derivation to minimize the number of ventricular catheters and possible shunt malfunctions as well as postoperative CSF-related complications. The goal of the neuronavigation-guided catheter perforation of the septum pellucidum without endoscopy was to perform a less invasive surgical procedure by creating an effective CSF outflow from both dilated lateral ventricles with only one ventricular catheter and unique shunt system.

MATERIALS AND METHODS

A neuronavigation-assisted single transseptal biventricular catheter implantation with distal peritoneal shunt system was performed in 11 patients with posthemorrhagic hydrocephalus and accentuated lateral ventricles dilatations between 2001 and 2010. In all these cases, following a biventricular external drainage or lysis of intraventricular clot, the size and morphology of the third ventricle were not disturbed. However, all patients showed a progressive dilatation of both lateral ventricles on repeated radiological studies. Moreover, sequential attempts of temporary drainage occlusion on both sides were unsuccessful. A unilateral ventriculoperitoneal (VP) shunt insertion was considered inappropriate to treat these patients. The patients’ clinical features are listed in Table 1. In two of the 11 patients, hydrocephalus was attributed to IVH associated with prematurity. Six patients had previous aneurysmal IVH (four anterior communicating and two pericallosal artery aneurysm). Two patients presented with IVH due to hypertension and one – due to arteriovenous malformation (AVM). The common characteristics of these patients were not only the massive supratentorial biventricular hydrocephalus, but also the accentuated neurological deterioration at admission with a Glasgow coma scale from less than 7 points. In all cases, dilatation of both lateral ventricles with associated clots casting phenomena were observed in CT scans taken during admission. Despite the rush implantation of two external drainages after admission and the fact that in four cases an additional neuronavigation-guided stereotactic catheter lysis was performed using multiplanar targets, both lateral ventricles remained dilated. The averaged interval between IVH and shunt placement was 4.2 weeks. Owing to space reduction between the both dilated lateral ventricles with thinning of the involved neural structures, the implantation of a unique transseptal neuronavigation-assisted biventricular catheter with at least 2 cm additional perforations could always be easily performed. This procedure was thought to minimize the number of ventricular catheters and reduce the patient’s surgical trauma. The biventricular-implanted catheter was finally connected to a programmable valve system with distal peritoneal drainage (Codman-Medos programmable shunt, Medos SA, Le Loche, Switzerland). The assessed protein and red blood cell counts levels in this series did not exceed 200 mg/dl and 100 rbc/mm³ at the time of shunt implantation.

Neuronavigation was employed to accurately establish the catheter surgical corridor (trajectory) across the lateral ventricles and throughout the septum pellucidum. Free-hand transseptal biventricular catheter implantation was performed under assistance from the Vector Vision (2) neuronavigation systems (BrainLab AG, Munich, Germany). The frontal entry point was located 3.2-4.6 cm from the middle line and 1.8-3.2 cm in front of the coronal suture. The target point was set 0.8-1.5 cm behind the genu of the corpus callosum and at least 1 cm above the fornix. To evaluate the impact of this technique, the inpatients charts, the neurological outcome [assessed 6 months after the event with the Glasgow outcome scale (GOS)], the postoperative radiological examinations, and ultrasound examinations were individually reviewed.

RESULTS

Accurate planning of the approach and determination of
Table 1: Clinical data, management and outcome of the patients

| Case No. | Gender | Age (yr) | Bleeding source | Admission GCS | Initial therapy | Postshunt implantation examination | Complications | Outcome GOS |
|---------|--------|----------|-----------------|---------------|----------------|-----------------------------------|---------------|-------------|
| 1       | F/43   | 43       | Anterior communicating artery aneurysm | 5             | 2 EVD + clipping | CT: TS BV catheter | vaso/spasm-related infarct | 4            |
| 2       | M/58   | 58       | Arteriovenous malformation | 6             | 2 EVD + AVM-removal | CT + MRI: TS BV catheter | pneumonia, renal insufficient | 4            |
| 3       | M/61   | 61       | Spontaneous ICB with IVH | 7             | 2 EVD + thrombolysis | CT: TS BV catheter | pneumonia | 3            |
| 4       | M/72   | 72       | Anterior communicating artery aneurysm | 4             | 2 EVD + coiling and thrombolysis | CT + MRI: TS BV catheter | pneumonia | 4            |
| 5       | F/52   | 52       | Pericallosal artery aneurysm | 7             | 2 EVD + clipping and decompressive craniotomy | CT + MRI: TS BV catheter | pneumonia | 4            |
| 6       | M/3 months | 3 months | IVH associated with prematurity | 5             | 2 EVD | MRI + US: MV catheter | on delayed CT control | 3            |
| 7       | M/63   | 63       | Spontaneous ICB with IVH | 6             | 2 EVD + thrombolysis | CT: TS BV catheter | Pneumonia | 3            |
| 8       | F/67   | 67       | Anterior communicating artery aneurysm | 5             | 2 EVD + coiling and thrombolysis | CT: TS BV catheter | vaso/spasm-related infarct | 3            |
| 9       | M/1 month | 1 month | IVH associated with prematurity | 4             | 2 EVD | MRI + US: MV catheter | Vaso/spasm-related infarct | 3            |
| 10      | F/62   | 62       | Anterior communicating artery aneurysm | 6             | 2 EVD + clipping | CT + MRI: TS BV catheter | Vaso/spasm-related infarct | 3            |
| 11      | F/43   | 43       | Pericallosal artery aneurysm | 7             | 2 EVD + clipping | CT: TS BV catheter | Vaso/spasm-related infarct | 3            |

GCS: Glasgow coma scale, GOS: Glasgow outcome scale

the ideal trajectory were possible in all the cases. Figure 1 illustrates the planning of three different cases. The mean registration error of the system, given as a computer-calculated value, was 2.1 mm (0.4–3.2 mm).

Catheter implantation across the septum pellucidum was successfully performed in all patients. Figure 2 illustrates two patients with satisfactory clinical and radiological results. Using neuronavigation, the tip of the probe was virtually elongated to about 10 cm and was closely held to the ventricle catheter. This made the continuous intraoperative verification of the catheter position during the procedure possible. The standard entry point for ventricular cannulation proved to be reliable for ventricular puncture and reduced the chances of malpositioning of the catheter. In all except for one case, delayed postoperative CT scans revealed an appropriate catheter position. Only one catheter, initially correctly implanted, lay monoventricular on delayed CT controls (case 6 of Table 1). However, the initial catheter-induced septum pellucidum fenestration still allowed CSF passage between both lateral ventricles and made additional surgical procedures unnecessary. No new neurological deficits or CSF fistulas were diagnosed after surgery. Over a median follow-up period of at least 6 months, none required additional ventricular catheter implantations or shunt revisions owing to insufficient CSF drainage. Radiological and clinical controls confirmed the good function of the shunts. Procedure-related complications (infection or bleeding) were not observed. Particularly, the CT scan controls did not reveal any midline bleedings. None of the patients developed any acute or delayed subdural collections. The neurological status of all these patients clearly improved several weeks after surgery. Six months later, an improved neurological status was observed with a GOS of 3 in six cases, 4 in four cases, and 5 in one case.

**DISCUSSION**

In clinical practice, the number of cases with a residual biventricular hydrocephalus following massive IVH is small. In this study, massive IVH presented with different etiologies and specific individual treatments for each bleeding source. However, in all these patients, the common accentuated neurological deterioration at admission with a Glasgow coma scale from less than 7 points always made necessary the early minimal invasive and effective treatment of the acute hydrocephalus. Several facts make the acute treatment of the hydrocephalus a first priority. Nishikawa et al.
Several authors have previously analyzed the possible use of intraventricular fibrinolysis for IVH associated with initial occlusive hydrocephalus. However, owing to the fact that even after effective thrombolysis of the clot into the lateral ventricles, the residual clots into the third and fourth ventricles still make the CSF passage difficult, new additional therapeutic modalities are frequently required. Unfortunately, the clearing effect of intraventricular fibrinolysis takes sometime longer. During this period, several patients develop a progressive biventricular supratentorial dilatation owing to the residual obstruction of the distal ventricle system and consequently an increased need for shunt procedures. Despite the fact that combined treatment approach of intraventricular fibrinolysis and early lumbar drainage could markedly reduce the need for shunt surgery, the residual communicating posthemorrhagic hydrocephalus frequently makes a shunt implantation necessary. Preterm infants with severe IVH, initially treated with shunting procedures, frequently require several reinterventions within the following years. A frequent option in such children has been a subcutaneous reservoir implantation. This is also a suitable and safe treatment for posthemorrhagic hydrocephalus in premature infants. However, it is more effective for obstructive hydrocephalus than for communicating hydrocephalus. Another minimal invasive procedure employing image-guided neuroendoscopy is being increasingly used in an attempt to reduce the morbidity associated with shunt devices. This procedure has a particularly useful application in the pediatric population for the treatment of complex hydrocephalus and arachnoid cysts.
Nevertheless, it is seldom employed in cases with fresh hemorrhagic obstruction of the CSF circulation. Despite the fact that a recent study reported some attractive good results, a blurred field of vision and distorted ventricular anatomy remain a challenge for any endoscopic neurosurgeon.[18]

A neuroendoscopic fenestration of the septum pellucidum has been previously described as beneficial in cases of unilateral hydrocephalus.[7,9,16,26] This procedure seems to be a reasonable alternative to shunt implantation.[20] Unfortunately, in posthemorrhagic hydrocephalus with accentuated dilatation of both lateral ventricles, the neuroendoscopic fenestration of the septum pellucidum alone does not resolve the distal residual CSF passage difficulties. In this study, a transeptal CSF derivation and shunt implantation draining both lateral ventricles was found to be an appropriated alternative solution for this problem. Because of the accentuated ventricle dilatation with marked thinning of the septum pellucidum in all of our patients, determination of the fenestration’s site was not difficult. As it was previously reported, accurate placement of ventricular catheters with neuronavigation additionally decreased the incidence of proximal catheter failure.[1,21,27,30] In this study it also reduced the complexity and timing of the surgical procedure as well as potential infection’s risks associated with the use of multiple shunting systems.

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